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English Translation  
of  
**BHARATIYA JYOTISH SASTRA**  
(History of Indian Astronomy)

by

Sankar Balakrishna Dikshit

[Translated by Prof. R. V. Vaidya, M. A. B. T.]

**PART II**

History of Astronomy during the Siddhantic and Modern periods



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## PREFACE

A treatise in Marathi "Bharatiya Jyotish Sastracha Prachin Ani Arvachin Itihas" by Sankar Balakrishna Dikshit, first published in the year 1896, is perhaps the only book on the history of the Indian Astronomy from ancient to modern times. Publication of an English translation of this monumental work was undertaken by the Meteorological Department of India in accordance with a recommendation by the late Professor M. N. Saha, D.Sc., F.R.S., Chairman of the Calendar Reform Committee. The first part of the English translation of this treatise, namely, "Bharatiya Jyotish Sastra, Part I" containing a history of Indian Astronomy in the Vedic and Vedanga period from ancient times upto 1000 B.C. was published by this department in 1968. The present volume contains an English translation of the remaining parts of the original treatise on the Siddhanitic and the Modern periods.

The translation of this treatise from Marathi to English was made by the late Professor R. V. Vaidya, a Marathi scholar and former Superintendent of Shree Jiwanji Observatory of Ujjain. He was also a member of the Calendar Reform Committee. This translation was also touched up by the late Professor P. C. Sen Gupta, a renowned Professor of Hindu Astronomy of the Calcutta University. The final editing of this volume has been made under the supervision of Shri A. Bandyopadhyay, Director, Positional Astronomy Centre of the Department at Calcutta. We expect this English translation of Dikshit's excellent treatise will help scholars, both in India and abroad, to appreciate the remarkable achievement of Indian Astronomy during the ancient and medieval periods.

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16 September, 1981  
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# **BHARATIYA JYOTISH SASTRA**

## **PART II**

**History of Astronomy during the Siddhantic and Modern Periods**

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# CONTENTS

PAGE	
iii	Preface

## PART TWO

### HISTORY OF ASTRONOMY IN JYOTIṢA SIDDHĀNTA PERIOD

#### 1. GANITA SKANDHA (MATHEMATICAL BRANCH)

#### (A) : MADHYAMĀDHIKĀRA (ADHIKĀRA ON MEAN PLACES)

#### Chapter I.—History of Astronomical Works and Computation of Mean Places of Planets etc.

1	Foreword
2	The Group of Five Ancient Siddhāntas
3	Pitāmaha Siddhānta
6, 47	Vasiṣṭha Siddhānta
6	Different Versions of Vasiṣṭha and Romaka Siddhāntas
9	Romaka Siddhānta
13	Measures of the Year According to Different Works on Astronomy
14	Puṣṭa Siddhānta
20, 36	Śūrya Siddhānta
25, 26, 39	The Pauruṣa (Human) Authors of Astronomical Works Before Śaka 420 (Lāṭā, Śiṣṭha, Pradyumna, Vijayanandi)
26	The Five Modern Siddhāntas
27	Āpanuṣeṣya, i.e., Divine
27	The Numbers of Revolutions and Other Elements Mentioned by All the Five Siddhāntas
28	The Yuga System
29	General Description
30	The Dates of the Five Siddhāntas
36	Śūrya Siddhānta Subject Matter and Date
37	Māya
38, 65	Prolemy
38	A Relation Between the Two Śūrya Siddhāntas
39	Lāṭā
41	When Held in Reverence
41	Works Following Modern Śūrya Siddhānta

(vii)

PAGE	
43	Diffusion . . . . .
44	Terminology . . . . .
44	Elja (Corrections) . . . . .
45	Problems . . . . .
46	Soma Siddhanta . . . . .
47	Vasistha Siddhanta . . . . .
47	Subject Matter . . . . .
48	Different Versions . . . . .
48	Romasa Siddhanta . . . . .
48	Brahma Siddhanta Cited by Sakalaya . . . . .
49	Author . . . . .
49	Subject Matter . . . . .
49	Date . . . . .
51, 188	Aryabhata I (Birth Saka 398) . . . . .
51	Name . . . . .
51	Three Schools . . . . .
52	Numerical Code . . . . .
53	Motions and Revolutions of Planets . . . . .
54	The Yuga System . . . . .
55	Date . . . . .
55	Length of a Year . . . . .
57	Diurnal Motion of the Earth . . . . .
58	Karsa Work of Aryabhata . . . . .
60	His Calibre . . . . .
61	Planetary Corrections . . . . .
67	Aphelia and Nodes at the Commencement of Kaliyuga . . . . .
73	Varahmihira (Saka 427) . . . . .
80	Sripata and Vigraha . . . . .
80	Brahmagupta (Saka 520) . . . . .
81	Other Versions of Brahma Siddhanta . . . . .

# CONTENTS

82	The Number of Revolutions and Other Elements Mentioned in the Brahma Siddhanta
83	Length of Year
85	Sayana
85	Correcting the Planetary Elements and Observations
86	Subject Matter of Brahma Siddhanta
86	Interpolation and Yogas
87	Khaṇḍakhādya
91	Corrections
92	Condition of Astronomy
92	Lalla (About Saka 560)
95	Padmanābha
95	Śridhara
95	Mahāvira (About Saka 775)
95, 192	Aryabhata-II (About Saka 875)
95	His work
99	Paraśara Siddhanta
100	Balabhadra
100	Bhaṭṭopala (Saka 888)
102	Caluvedra Pithudaka Swami
103, 193	Śripaṭi (Saka 961)
103	Varuṇa
104	Rājamaṅgyaka Karaṇa (Saka 964)
106	Karaṇa Kamala Mīranda (Saka 980)
108	Karaṇa Prakāśa (Saka 1014)
110	Abhevaṇ Karaṇa (Saka 1021)
112	Karaṇottama (Saka 1038)
113	Madhava (Birth date about Saka 1000)
113	Abhiṣatīrtha Cintamani
114	Other Works and Authors Before Saka 1072
114	Bhaskarārya (Birth Saka 1036)
118	Subject Matter of Siddhanta Siromani
121	Karaṇa Kautāhala

# CONTENTS

123	Anantadeva (Saka 1144)
123	Adityapratap Siddhanta
123	Va Vilala Kocanna (Saka 1220)
123	Grahasiddhi (Saka 1238)
125	Narmada (About Saka 1300)
125	Padmanabha (About Saka 1320)
125	Damodara (Saka 1339)
127	Makaranda (Saka 1400)
127, 194	Kesava
128	Kesava II (Saka 1418)
129	Observations
130	Ganaka Daivajanya (Saka 1442)
132	Grahalaghava
133	His Specialty
134	Planetary corrections
139	Kalpadruma Karana
139	Lakshmidasa (Saka 1422)
140	Jaharna (Saka 1425)
144	Surya (Birth Saka 1430)
146	Dhruvacharya
147	Ananta (About Saka 1480)
149	Raghunatha (Saka 1484)
149	Raghunatha (Saka 1487)
149	Kripatma
149	Dinkara (Saka 1500)
150	Gangadhara (Saka 1508)
151	Ramabhatta (Saka 1512)
151	Shruti (Saka 1512)
151	Vijaya (Saka 1530)
155	Mahat (About Saka 1524)
156	Vishakhina

# CONTENTS

PAGE

xi

157	Nṛsiṃha (Birth Saka 1508)
157	Śiva (Birth Saka 1510)
157, 166	Kṛṣṇa
159	Raṅgaṇaṭha (About Saka 1525)
160	Gṛaha Prabodha (Saka 1541)
161	Muniśvara (Birth Saka 1525)
162	Divākara (Birth Saka 1528)
162	The Siddhantaiva Viveka of Kamalākara (Saka 1530)
164	Raṅgaṇaṭha (Saka 1565)
165	Siddhantaṛja by Nityānanda (Saka 1561)
166	Kṛṣṇa (Saka 1575)
167	Pāñcāṅgakautuka by Ratnakāṇṭha (Saka 1580)
167	Vārjika Tantra by Viddāna
168	Pharṇeśaṇa Prakāśa by Jajādhara (Saka 1626)
168	Dadabhata (Saka 1641)
169	Jayasimha (Saka 1650)
171	Vaiṣṇava Kāraṇa by Śaṅkara (Saka 1688)
172	Gṛahagṛaha Cintāmaṇi by Maṇḍana (Saka 1696)
173	Brahma Siddhantaśāstra (Saka 1703)
174	Yantrarāja Ghaṇaṇa by Mathuraṇṭha (Saka 1704)
174	Cintāmaṇi Dīkṣit (Birth about Saka 1658)
174	Raghava (Saka 1732)
175	Tiṇi Parjāta by Śiva (Saka 1737)
175	Dinkara
176	Yajñeśwara, Alias Bābā Jōṣṭi Rode

177	Naimha, Alias Bīṣṭava (Birth Saka 1743)
178	Nīlambār Sarmā (Birth Saka 1745)
179	Vināyak, Alias Kero Lakṣmaṇa Chhāre (Birth Saka 1746)
180	Vīraji Rāghavātha Lele (Birth Saka 1749)
181	Cintāmaṇi Rāghavātha Aṣṭya (Birth Saka 1750)
182	Kṛṣṇa Śaśurī Gopāle (Birth Saka 1753)
183	Living Authors of Astronomical Works
183	Venkates Bāpūji Ketkar (Birth Saka 1775)
184	Baī (Jaogadhar) Tilak (Birth Saka 1778)
185	Vināyak Paṇḍurang Khāṇḍepurkar (Birth Saka 1780)
185	Sudhākara Dīvedī (Birth Saka 1782)
186	From Al Beruni's 'Indica'
187	Spread of Hindu Astronomy Among Muslims
187	Al Fazari, Yakub-Bin-Tariq and Abu Al Hasan
187	Pūliśa Siddhanta
188	Aryabhata I
188	Vārāha Mihira
188	Brahmagupta
188	Lalla
189	Sridhara
190	Bīṣṇuśaṅkara Karaṇa
190	Belaṭhādra
190	Karaṇasāra by Viṭṭhala (Saka 821)
190	Laghunāśa by Mūṇḍī (Saka 854)
192	Aryabhata II
192	Pitru Śikha
192	Śhulopala
192	Karaṇa Tilak by Vijayaṇḍī (Saka 888)
193	Belaṭhādra-Belaṭhādra
193	Other Karaṇa Works

# CONTENTS

xiii	Page	Other Works and Authors Belonging to Periods Later Than Saka 950
193		Sripati
193		Kesava
194		Graha Siddhi by Mahadeva
194		Kamadhenu Karana by Mahadeva (Saka 1289)
194		Gadgadhara (Saka 1356)
195		Nrsimha (Saka 1480)
195		Chapter II—The Universe.
196		Orbital Length in Yojanas
196		Moon's Distance from the Earth
196		Distance of Planets from the Earth
196		Earth's Radius
199		What Distance Does 'Yojana' Indicate
199		To Calculate the Distance in Degrees
200		Support for Universe
200		Attraction
201		Description of the Earth
201		Views of the Sky
201		Meru and Seven Worlds
202		Atmosphere Enveloping Earth
202		Pravaha and Other Kinds of Winds
202		Revolutions of Planets
203		Light of Planets
203		Viksepas of Planets
206		Chapter III—"Ayana Calana" or Displacement of Solstitial Points
206		Measure of Displacement of Solstitial Points
212		Does the Equinoctial Point Oscillate or Revolve
213		Accuracy of Ayana Motion
214		Findings of Other Nations Regarding the Rate of Precession
214		Accuracy of Zero-Precession Year
215		How Ayana Motion and the rate of Zero-Precession Were Determined
218		Association of the Junction-Star of Revati with Ayana's Problem
218		When was Precessional Motion Finally Determined

Chapter IV—On Observations

221	General Description
221	Our Tradition Favours Observation
224	Description of Instruments
224	Gola Yantra or Armillary Sphere
226	The Cakra Yantra (The Disc Instruments)
226	The Cakra (Semi Circular Disc)
226	Turyagola (Turiya Yantra)
226	The Gola Instrument (Globe Instrument)
226	The Nadivalaya
226	The Ghatika Instrument
226	The Sanku (Gnomon)
227	The Phalak Instrument
227	Yasti Yantra (Pole Instrument)
228	Ancient Observations of Westerners
230	Sarvabhadra Yantra
230	Yantra Raja
231	Dhruva-Bhrama-Yantra
232	Yantra Cinikampl
232	Prasada Yantra
232	Golanda
233	Observatories

(2) : ADHIKARA ON TRUE PLACES

Chapter I—True Places and Motions of Planets

242	Mandapadi-Dimensions of the Epicycles of Apsis and Their Radii or Max. Value of the Equation of Centre
243	Dimensions of the Epicycles of Apex and Their Radii or Max. Value of the Annual Parallax
243	Maximum Values of Equation of Centre
248	Sines and Radius
249	Declination

# CONTENTS

PAGE

XV

## Chapter II—Panchānga (Almanac)

250	A Study of Different Eras
250	Expired Year and Current Year
252	The Kali Era
252	The Saptarṣi Era
252	The Vikrama Era
253	The Christian Era
253	The Śaka Era
254	The Cedi or Kalcuri Era
254	The Gupta Era
254	The Valabhi Era
254	Hijri Era
255	The Bengali San
255	The Vilayati San
255	The Armi Era
255	The Fasali San
256	The Sur-San or Sahur-San
256	The Harṣa Kala
257	The Magi San
257	The Kollam Era or Paraśurama Era
257	The Nevari Era
257	The Calukya Era
257	The Simha Samvat
258	The Lakṣmanāsenā Era
258	The Ilahi Era
258	The Rājāśaka or Rājyābhīṣeka Era (of Śivaji)
259	The Differences in the Year Numbers of All Eras Current as well as obsolete in Śaka 1800
260	The Lunar and Solar Measures
260	Beginning of Year
266	First Point of the Zodiac
266	Jovian Year-Samvatsara
267	Sixty Samvatsaras
268	Luni-Solar Samvatsara

268	Jovian Year in South
269	Purimanta and Amanta Months
269	Names of Months and Intercalary Months
271	Mean and True Intercalary Months
272	Intercalary Months North of the Narmada
273	Beginning of Months
274	Parts of the Panchanga
274	When Did the Five Parts Come Into Use
277	When 'Yogas' Came Into Existence
279	Shorter Nakshatra Divisions
280	Almanacs in Use in Different Provinces
280	Three Schools
281	Almanac : Its Calculation and Circulation
284	The Kero pand or New Patavardhani Almanac
285	Digambara Panchanga (Raghuvaradharaya)
286	Bapudeva's Panchanga
287	Other Precise Panchangas of the Nirayana School
287	The Sayana Panchanga
290	Study of Almanac Reform
291	Study of Ayanamshas
293	Definition and Nature of the Sayana and Nirayana Almanacs
293	Correct Planetary Positions Obtainable by Any System
295	What is the Actual Error in the Grahalaghava and other Almanacs
297	Acceptability of the Sayana and Nirayana Systems
297	Preamble
298	The Sayana System
298	Logical Aspect
299	Historical Aspect
302	First, the First Nakshatra of the Rainy Season
302	Days for Mithya Nakshatra
302	Religious Aspect
303	Doubts Resolved
306	Sayana System Displaces Stars
306	Culture and Other Name will not be justified

# CONTENTS

xvii

PAGE

307 Seasons Displaced by Nirayana System . . . . .

307 Nakshatras Displaced Even in Nirayana System . . . . .

310 Cultural Terms not Associative . . . . .

314 Pros and Cons Weighed . . . . .

315 Conclusion . . . . .

315 Complete Revolution of the Equinox . . . . .

321 Practical Aspect . . . . .

322 Astrological Aspect . . . . .

323 The Best and Most Acceptable Solution . . . . .

324 Another Solution . . . . .

326 Third Solution . . . . .

326 New Work Necessary . . . . .

(3) : THE ADHIKARA ON THREE PROBLEMS . . . . .

329 (4), (5) : ADAIKARAS ON ECLIPSES OF THE SUN AND THE MOON . . . . .

329 (6) : ADHIKARA ON SHADOW . . . . .

330 (7) : HELIACAL RISING AND SETTING . . . . .

336 (8) : ŚRĀNGONNATI OR ELEVATION OF THE MOON'S CUSPS . . . . .

336 (9) : CONJUNCTIONS OF PLANETS . . . . .

336 (10) : BHĀ-GRAHA-YUTI OR CONJUNCTION OF PLANETS WITH STARS . . . . .

336 Longitudes and Latitudes of Stars . . . . .

338 Polar Longitudes of Junction Stars and Some Other Stars . . . . .

339 Polar Latitudes of Junction Stars and Some Other Stars . . . . .

340 Celestial Longitudes of Junction Stars . . . . .

341 Celestial Latitudes of Junction Stars . . . . .

343 Number of Stars in Asterisms . . . . .

345 Junction Stars of Nakshatras . . . . .

348 Catalogues of Stars . . . . .

348 Identification of Stars . . . . .

349 Origin of Nakshatra System . . . . .

1 A

1 D.G.O/69

Page.	(ii) : MAHAPATA	352
	II. SAMHITA SKANDHA (THE SAMHITA BRANCH)	
353	Subject-Matter of Samhita	
355	Muhurta Works	
357	Ratnakosa	
357	Ratnamala	
357	Rajamartanda.	
357	Visha Vrodavana	
358	Vishapatala (by Sarabhadhara)	
358	Muhurta Tatra	
359	Visha Patala (by Pitambara)	
359	Jyotisa Darpana	
359	Muhurta Martanda	
360	Todaramanda	
360	Muhurta Cintamani	
360	Muhurta Cudamani	
360	Muhurta Kalpadruma	
360	Muhurta Mala	
361	Muhurta Dipaka	
361	Muhurta Gaganadi	
361	Muhurta Sindhu	
361	Vidvajana Vallabha	
362	Adbhuta Sagara	
362	Vyavahara Pradipa	
363	Jyotirvidyabharata	
363	Jyotirbandha	
363	Sakuna	
	III. JATKA SKANDHA (NATAL ASTROLOGY)	
364	Definition	
364	Kundali (Horoscope)	

Page	
366	Babaji Krishnaji Patwardhan . . . . .
367	Mutual Relation Between Man and Man . . . . .
367	Science of Astrology . . . . .
367	History . . . . .
368	Beginning of the Present System of Astrology . . . . .
370	History of Works on Astrology . . . . .
370	Parasari . . . . .
371	Jaiministara . . . . .
371	Bhigu Saphila . . . . .
372	Nadi Granthas . . . . .
372	Yavanacharya . . . . .
372	Kerala System . . . . .
375	Hora Astrology . . . . .
376	Ramul . . . . .
376	Dreams . . . . .
377	Tajik . . . . .
<b>EPILOGUE</b>	
379	What Foreign Element Has Entered Indian Astronomy . . . . .
379	Nakshatra System not Babylonian . . . . .
380	Views of Europeans . . . . .
382	Colebrooke . . . . .
383	Whitney . . . . .
388	Burgess . . . . .
390	Thibaut . . . . .
393	Verdicts Reviewed . . . . .
393	Mathematical Branch . . . . .
394	Other Siddhantas Older Than Romaka . . . . .
395	Romaka Older Than Ptolemy . . . . .
395	Quintet Older Than Ptolemy . . . . .
397	Mega and Other Terms . . . . .
398	What We Borrowed From Greeks . . . . .
401	Our Independent Efforts . . . . .
18	I D.G.O./69

22

## 403

[illegible]

[illegible]



## PART TWO

### HISTORY OF ASTRONOMY

IN

### JYOTIṢA SIDDHĀNTA PERIOD

#### I GAṆĪTA SKANDHA (MATHEMATICAL BRANCH)

#### A : Madhyamādhikāra (Adhikāra on Mean Places)

#### CHAPTER I

#### *History of astronomical Works and Computation of mean places of*

*Planets etc.*

#### FORWARD

As mentioned in the INTRODUCTION,\* the author proposes to discuss the history of the science of Astronomy from about 500 years before Śaka era to this day, and in the beginning, this first chapter of the *Madhyamādhikāra* i.e. a section on mean places) under the GAṆĪTA SKANDHA (i.e. a Branch of Mathematics) will deal with the history of astronomical works and the question of computing the mean motions and places of planets.

The knowledge of astronomy as developed during the Vedic and Vedāṅga Jyotiṣa periods and described in Part I, was considerable as compared with the pace of general progress during the period; but it would appear very meagre, when compared with the ability (developed in a later period) to predict the true positions of planets. It appears that some works might have been compiled during the interval between these periods. There may be some Samhitā works of that type; but they are either not available now or have not been seen by him. The period of Siddhāntic astronomy can somehow be linked with the ancient period. This point will be discussed later on; but we have no information as to how the knowledge of astronomy reached the highest stage of calculating the true motions and places of planets, how observations used to be taken and how the motions of planets were finally fixed after comparing the different observations. The oldest of astronomical (Siddhānta) works reveal a sudden rise in the standard of astronomical knowledge. Those who raised the standard of such knowledge through their works were naturally regarded as superhuman, and thus arose the popular belief that the available ancient works on mathematical astronomy are regarded as 'apauruṣeya' (i.e. not compiled by any mortal man), and it is clear that this belief has been formed later.

Because these works were regarded as superhuman, they naturally did not include the description of subjects like observations. There seems to be another very strong reason for this omission. Looking to the conditions of those days when as a rule, shorter the works, the easier they were to commit to memory, such works dealt with only the rules of calculating the motions and places of planets, and they appear to have avoided length by omitting the underlying theory.

\*Published in part I of the book

I DGO/69

The author proposes to deal with all works on astronomy in chronological order in this chapter on mean places. Their points of differences, if any, with matters pertaining to other *Adhikāras* from different works, as also some special points worth mentioning, have been treated in subsequent chapters; otherwise, all information about the works has been given in this very chapter on mean places. Some works are considered divine while some authors have more than one book to their credit; hence, the following account is arranged under the names of authors, and at places, and at titles of their works.

The oldest known works on astronomy are the five *Siddhāntas*—the *Sūrya Siddhānta* and others. These are regarded as divine. They are again of two kinds. The *Pāncasiddhāntikā* of *Varāhamihira* mentions the *Saura* and other four *Siddhāntas*; but at present they are not available. The *Pāncasiddhāntikā* simply provides clues to their elements. The author calls them the 'ancient *Siddhānta Pāncaka*' or 'group of five ancient *Siddhāntas*'. There are five other *Siddhāntas* likewise entitled the *Saura*, which are at present available. He calls them 'the modern group of five *Siddhāntas*'. These will presently be dealt with. First he takes up for consideration the group of five ancient *Siddhāntas*. These belong to the 5th century before *Saka* era. Some of them may belong to an even earlier period.

#### *The group of five ancient Siddhāntas*

The following are the *Siddhāntas* mentioned by *Varāhamihira* :—

प्राचीनसिद्धान्तपञ्चकम् ।  
प्राचीनसिद्धान्तपञ्चकम् ॥

*Pauliṣa*, *Romaṇa*, *Vasiṣṭha*, *Saura* and *Paṭāma* are the five *Siddhāntas*. The elements described by the *Pāncasiddhāntikā* show that the *Siddhāntas* were different from the five modern *Siddhāntas*. Not only are these not available at present, but even the original work, entitled *Pāncasiddhāntikā* is not available and so, not much is known to any one on this side. Two copies of the work brought from *Kashmir* by *Dr. Bühler* are preserved in the Government collection of Manuscripts in the *Deccan College* (See *Rcg.* No. 37 of 1874-75 and No. 338 of 1879-80); but these are very incorrect and incomplete and one is unable to find, at places, where one *śūrya* (couplet) ends and the next one begins. The author has written out for himself a copy from the two versions, and calculations made therefrom have shown that the *Sūrya* and other *Siddhāntas* described in it, are different from the modern ones, in that they differ in the length of the year and the motions of planets. The astronomical works compiled during the last 800 years do not show that any one knew that there existed before a *Sūrya-Siddhānta* different from the modern one. He came to know of their existence in 1887 and no doubt need be entertained about it, since this can be proved by calculations and by other evidence. The booklet of the *Pāncasiddhāntikā* is very incorrect and the major portion of it is unintelligible for want of a commentary; however many important points have been understood. \*The author would, therefore, describe briefly the five *Siddhāntas* in the order of the dates of their compilation as found by him.

\**Dr. Thibaut* published in 1889 A.D. the *Pāncasiddhāntikā* based on the *Deccan College* version. It also gives a new commentary by *Sudhākara Dvivedi*. The author could not find time to read the whole of it up to now. However all the important information which he could glean from the *Pāncasiddhāntikā* has already been given above.

Varāhamihira, in the very first chapter of *Pañcasiddhāntikā*, observes as follows :—

प्राचीना\* प्राचीना तत्त्वानामेव येषः येषः ॥  
स्येतरः साध्याः प्राचीना प्राचीना ॥ ४ ॥

"The Siddhānta made by Pāuliśa is accurate ; near to it stands the Siddhānta by Romaka ; more accurate still is the Sāvitra (Saura). The two remaining ones are far from truth."

This shows that the Pāuliśa Siddhānta was very clear at the time of the compilation of *Pañcasiddhāntikā*, which means that its calculations very much agreed with the actual observed positions. The Romaka was nearer to it in correctness. The Sūrya-Siddhānta was better than both and the remaining two (Vasiṣṭha and Pītāmaha) were far removed from correctness meaning that their calculations did not agree with the observed results. The Pītāmaha Siddhānta and Vasiṣṭha Siddhānta must have been the oldest of the five, and of these two, in the author's opinion, Pītāmaha Siddhānta must have been the more ancient. The reasons for this will be given later on. Let us now consider the Pītāmaha Siddhānta.

#### PITĀMAHA SIDDHĀNTA

##### The Subject matter

The basic principles underlying the Pītāmaha Siddhānta have been given in the 12th chapter of the *Pañcasiddhāntikā*. That chapter contains only five *verses* (couplets). Nowhere else in the *Pañcasiddhāntikā* is found anything about this Siddhānta. The first two of the five couplets run thus :—

प्राचीनाः पञ्च यत् प्राचीना प्राचीना प्राचीना ॥ अथ प्राचीना प्राचीना प्राचीना ॥  
प्राचीना प्राचीना प्राचीना प्राचीना प्राचीना ॥ प्राचीना प्राचीना प्राचीना ॥ १ ।

"According to the teaching of Pītāmaha, five years constitute a yuga of the sun and the moon. The *adhimāsas* occur after thirty months and an omitted lunar day (avam) once in sixty three days. Lessen the time of the Saka King by two and divide the remainder by five ; with the remaining years find the *aharagaṇa*, counting from the first day of the light half of Māgha. The *Aharaṇa* thus found begins with sunrise".

The fifth couplet describes the method of calculating the length of the day :—

प्राचीना प्राचीना (११) प्राचीना प्राचीना प्राचीना ॥

"Multiplying (the number of days elapsed after winter solstice or the number of days to go before the end of the *ayana* beginning with summer-solstice) by 2 divide by 61. Add 12 (*muhūrtas*) to the quotient, and the result will be the length of the day".

\*The author copied out the couplets from the *Pañcasiddhāntikā*, exactly as they are written in his book. Dr. Thibaut has introduced new readings in the next and he has accepted at places only such of them which were considered suitable.

†The word 'hinam' in this couplet is incorrect ; the proper word must be 'yuktam'. The first half of the couplet is incorrect and has not, therefore, been given here, but it means nothing more than that has been given above within brackets.



not similar to the Brahmagupta Siddhanta. This shows that the Brahma Siddhanta to which Brahmagupta has referred as containing mathematical explained by Brahma, must have been different from the Brahma Siddhantas of Sakalya Samhitā and Viṣṇudharmottarapūra and it must be the same as the Pītāmaha Siddhanta of the Pāṇcasiddhāntikā. The Vedāṅga Jyotiṣa does not deal with the calculation of planets other than the sun and the moon; and the Pītāmaha Siddhanta of the Pāṇcasiddhāntikā also describes the calculations of the sun and the moon only. Varāhamihira has given the calculations of all planets in the case of only the Surya-Siddhanta out of the five Siddhantas and mentions nothing about the planetary calculations contained in the Pītāmaha Siddhanta. It must have, however, contained the calculations of planets as remarked by Brahmagupta, and Varāhamihira appears to have omitted it, on finding that it did not agree with the actual observed places on account of lapse of time. A Pītāmaha Siddhanta, different from the one described in the Pāṇcasiddhāntikā, does not appear to have ever existed before Brahmagupta. The words "planetary calculations given by Brahma" occurring in Brahmagupta's work must certainly be referring to the Pītāmaha Siddhanta of the Pāṇcasiddhāntikā, and the remark, "a long time has elapsed" also refers to the same Pītāmaha Siddhanta. It follows, therefore, that it must have been compiled long before the Saka era.

Āryabhaṭa and Brahmagupta appear to have expressed veneration for the Pītāmaha Siddhanta only as a formality, because their Siddhantas and the Pītāmaha Siddhanta of the Pāṇcasiddhāntikā have nothing in common. It has already been pointed out in the course of the study of the Vedāṅga Jyotiṣa that Brahmagupta has openly found fault with the five-year Yuga system. Still, these arguments in no way affect the inference that there existed a Siddhanta known as the Pītāmaha Siddhanta before these two astronomers lived.

### The System

The Pāṇcasiddhāntikā gives in the beginning two couplets relating to the Pītāmaha Siddhanta, the first of which contains the expression,

अष्टाविंशतिर्द्वयः

meaning, "an intercalary month to be reckoned after 30 months". It has been shown in the study of Vedāṅga Jyotiṣa that the adoption of an intercalary month after 30 months causes a grave error; but this very couplet has been cited by Bhāṭṭopāla in his commentary on Vṛhatsaṃhitā in connection with the verse "*ekakamābdesu*" in Chapter 8. The reading there is "*adhimāso dwyagnisamāvimāso*" which means that an intercalary month is to be reckoned after 32 months. Again the same couplet is found in the commentary (Chapter I) by Mahādeo on Śrīpati's Ratnamālā and it also gives "adhimāso dwyagnisamāh" as the reading. It is strange that there is room for confusion due to doubtful readings at such an important place.

If it be assumed that Utpalā and Mahādeo changed the original reading viz. "trimsatbhirvīṃśasāh", why should they have substituted "dwyagnisamāh" as the reading? The intercalary month occurs after more than 32½ months, and hence, they could have as well substituted some words meaning 32½ or 33. It appears, therefore, that "dwyagnisamāh" must have been the original reading. According to the Vedāṅga Jyotiṣa one day (vithi) is suppressed after 62 days, while the above couplet mentions the suppression of one day

as occurring after 63 days (tithis). This shows that the Vedāṅga Jyotiṣa and the Pītāmaha Siddhānta are not similar to each other completely, and this also lends an additional support to the view that "dvyagñisamāh" must have been the original reading.

The number of intercalary months in 8 years comes to be 3 at the rate of one intercalary month in 32 months. This gives 99 as the number of lunar months in 8 years and 2970 as the number of tithis (lunar days); and  $47\frac{1}{2}$  lunar days will be suppressed during this number of tithis at the rate of one suppressed tithi per 63 lunar days. Hence, 8 years will be equal to 2922 $\frac{1}{2}$  savana days or one year will be equivalent to 365 days and  $21\frac{1}{4}$  ghatis. This measure of a year is more accurate than that found in the Vedāṅga Jyotiṣa.

The Pītāmaha Siddhānta existed before Āryabhaṭa, Varāhamihira, and Brahmagupta. As it had fallen into disuse in their times it is evident that it must have been compiled long before them. It is similar to the Vedāṅga Jyotiṣa but differs from it much. Brahmagupta's statement shows that it (the Pītāmaha Siddhānta) contained the calculations of Mars and other planets, which is not given in the Vedāṅga Jyotiṣa. It proves that a more accurate work known as the Pītāmaha Siddhānta was compiled sometime after the Vedāṅga Jyotiṣa and this is an important fact. If it were known how the places of Mars and other planets used to be calculated according to the Pītāmaha Siddhānta, it would have been found very useful in tracing the growth of Indian astronomy; but we have almost no hopes of obtaining the Pītāmaha Siddhānta now in its original form.

#### VASISHTHA SIDDHĀNTA

##### The Date

The Pañcasiddhāntikā contains 13 āryās (couplets) relating to Vasiṣṭha Siddhānta. The system described by it is somewhat different from that met with in other siddhāntic works. This fact and also the statement of Varāhamihira that "Vasiṣṭha is very inaccurate" leads one to infer that it must have been more ancient than the remaining three siddhāntas excepting the Pītāmaha Siddhānta.

##### The System

The thirteen couplets show that they mention nothing about planets other than the sun and the moon. The method of calculating tithis and nakṣatras is not similar to that of the present day. It mentions the rāśi (sign), amśa (degree) and Kālā (minutes) as the units and the subject of 'shadow' has been considered at length. Something has been told about the length of the day and the word 'lagna' (ascendant) has been used in a somewhat present day sense. The Vasiṣṭha Siddhānta, available at present, is in no way similar to the one existing before Varāhamihira's time and did not exist in his time. This question will be discussed again later on.

##### Different versions of Vasiṣṭha and Romaka Siddhāntas

Two versions of the Vasiṣṭha and Romaka Siddhāntas were known at the time of Brahmagupta (Saka 550). The case of Romaka Siddhānta will automatically be considered along with the evidence on the basis of which it is to be proved that there were two kinds of Vasiṣṭha Siddhānta. Let both of them, therefore, be considered here together.

Brahmagupta says at one place in his Siddhanta,

॥ गीतादीनामकारणैर्दत्तामहेषु ग्रहैर्वा ॥ तन्मन्त्रजनयन् गणयन्तान् तद्विपरतः ॥ ४६ ॥

अथवा ४६

"I describe the 'nakṣatranāyana' i.e. the method of calculating nakṣatras, which has been given by other Siddhāntas viz. Pāṇīśa, Romaka, Vāsiṣṭha, Saura, and Paitāmaha but not given by Āryabhaṭa".

He observes at another place,

अथवा कृतः सूत्रद्वयविचारोत्तमकविप्रयत्नैः ॥

अथवा. २४ अथवा ३.

"This very (beginning of a yuga) has been adopted by Surya, Indu, Pulisa Romaka, Vāsiṣṭha and Yavana".

Brahmagupta has cited as authority of the Surya and other Siddhāntas because these were in his favour. The Brahmagupta Siddhānta as a whole, appears to have launched a vigorous attack against Āryabhaṭa and others. He is, as it were, showering volleys of vituperation. Even then he has not made any direct attack against the group of first (Suryād) five Siddhāntas except the Romaka, and he has explicitly found fault with the Pattern, only once, as may be seen from the following couplet:—

युगान्वयैरकल्पः कालपरिवृत्तकः स्मृत्युक्तः ॥

यस्यान् रोमके न स्मृतिविराजो रोमकस्तस्यात् ॥ ४३ ॥

अथवा ४.

"The smṛti works mention yuga, manvantara and kalpa as the broad units of time. The Romaka has violated the Smṛtis since it does not mention them".

Brahmagupta, at another place, observes,

नादिकसंज्ञायां मय्यादिव्यवहारी च ॥

कुम्भवतीमहर्द्वयविचारोत्तमकविप्रयत्नैः मय्यात् ॥ ४८ ॥

युगान्वयैरकल्पः कालपरिवृत्तकः स्मृत्युक्तः ॥

मद्वयविचारोत्तमकविप्रयत्नैः मय्यात् ॥ ४९ ॥

भीषणं गीतादीनामकारणैर्दत्तामहेषु ग्रहैर्वा ॥

एतान्द्वयैरकल्पः कालपरिवृत्तकः स्मृत्युक्तः ॥ ५० ॥

अथवा ४९.

The gist

"Śrīgeṇa has compiled a 'kāṇṭha' (i.e. a patch work) entitled as Romaka, by borrowing elements from different Siddhāntas, e.g. (i) mean sun and moon,

moon's apogee, moon's node, Mars, Mercury, Jupiter, Venus, and Saturn from Lāṭa's work (ii) elapsed years of yugas and bhāgā (sidereal revolutions) from Vasiṣṭha (iii) the pāda (quadrants) from Vijāyanandī's works and (iv) mandocca, aphelia, paridhi (epicycle), nodes of planetary orbits and calculations of true places from Āryabhaṭīya. Viṣṇucandra has similarly compiled the Vasiṣṭha Siddhānta by borrowing the same elements".

It has been said above that Viṣṇucandra has borrowed the same elements from other works in compiling the Vasiṣṭha Siddhānta as Śrīṣeṇa had borrowed in compiling the Romaka Siddhānta, and it has also been observed that Śrīṣeṇa took the bhāgās and the elapsed years of yugas from the Vasiṣṭha Siddhānta and other information from other Siddhāntas and compiled another Vasiṣṭha Siddhānta. It, therefore, shows that there existed two kinds of Vasiṣṭha Siddhāntas and that this was known to Brahmagupta. One of them was the original Vasiṣṭha Siddhānta and the other was Viṣṇucandra's Vasiṣṭha Siddhānta, compiled by borrowing some elements from the first.

It has already been remarked before that Brahmagupta has abused Romaka Siddhānta as 'a violator of Smṛti', because it does not give the time units of yuga, manvantara and kalpa; but it has also been shown above that Brahmagupta himself says that Śrīṣeṇa picked up the figures for 'elapsed years of yuga' from the Vasiṣṭha Siddhānta while compiling the Romaka Siddhānta. Similarly, he again observes,

सृष्ट्यायै भवेत्समस्तं श्रीवशिष्ठसिद्धांते ॥

श. ११ अर्था ५५.

अर्थात्: भवति तद्वन्मूलं सृष्टिं यत्कालं ॥ श्रीवशिष्ठसिद्धांते ॥

श. २ अर्था ४९.

"That Śrīṣeṇa, Viṣṇucandra and other authors have mentioned 'Mahayugas as a multiplicity of yugas'...

"Śrīṣeṇa has not given true positions of Mars and others from the commencement of a yuga, as is done by Āryabhaṭa, but from the beginning of Mēṣa".

Thus, according to the statement of Brahmagupta himself, the Romaka Siddhānta by Śrīṣeṇa did contain the yuga system and from this (it can be inferred that) there were two Siddhāntas named Romaka, at the time of Brahmagupta—the one known as the original Romaka Siddhānta and the other, that 'compiled by Śrīṣeṇa'.

Most of the names of astronomers who lived before Brahmagupta and who have been mentioned in his Siddhānta, are found in the Pañcasiddhāntikā. However, the names of Śrīṣeṇa and Viṣṇucandra are not found in the Pañcasiddhāntikā which mentions only one Siddhānta each, named as Vasiṣṭha and Romaka. This goes to show that Śrīṣeṇa's Romaka Siddhānta and Viṣṇucandra's Vasiṣṭha did not exist before Śaka 427, and that only the original Romaka Siddhānta and the original Vasiṣṭha Siddhānta existed then and these are given in the Pañcasiddhāntikā only in summary form. According to Brahmagupta, Śrīṣeṇa and Viṣṇucandra borrowed the method of finding true places from Āryabhaṭa. This also shows that they compiled their res-

pective Siddhantas after Saka 421 while the Pañcasiddhāntikā leads to the conclusion that they were compiled after the Saka 427.

### ROMAKA SIDDHANTA

It has been pointed out above that out of the two Romaka Siddhantas described, only the original Romaka Siddhanta existed at the time of the Pañcasiddhāntikā. Let us now consider this Romaka Siddhanta.

A large portion of the Pañcasiddhāntikā has been devoted to Romaka Siddhanta. Three couplets of the first chapter beginning from the 8th describe the method of finding the 'ahargana'. The fifth couplet mentions the intercalary months and the suppressed tilth. All the 18 'āryas' of the 8th chapter are devoted to Romaka Siddhanta. They describe the calculations of the sun and moon, their true places and the method of calculating solar and lunar eclipses.

The very first couplet giving the method of calculating the 'ahargana' according to the Romaka Siddhanta runs thus :—

सर्वादिपदे (४२७) सत्यं शकतिवर्गात् सूर्यकालम् ॥  
 शकतिर्हो शनी पचात् शनिदिशतिः ॥ ८ ॥  
 अथवा ?

"Deduct the Saka year 427 from the number of that year for which the ahargana is wanted at the beginning of the light half of Caitra, when the sun was halset in Yavanapura, at the beginning of Tuesday".

This shows that the first lunar day of Caitra was a Tuesday.

A Karāṇa work is required to give the positions of planets as at the beginning or epoch of that work, for finding the planetary positions. These positions are termed 'kṣepaka'. The 'kṣepakas' as mentioned by the Pañcasiddhāntikā prove to be true for the mean Mesādi (Sun's entry into Aries), falling on the 14th Lunar day of the dark half of 'amānta' Caitra of Saka 427; i.e. on Sunday, the 20th of March, 505 A.D. There is no doubt that some of them are true for the moon and others for the midnight of that date. This point will be more clearly explained in the study of the Surya-Siddhanta later on. The next Sūtra 'pratiṇipada' (i.e. the first lunar day) after the 14th day of the dark half of Caitra, i.e. the first day of the light half of Vaiśākha, is seen to fall on Tuesday. Evidently this very 'pratiṇipada' was called the 'Caitra-sūtra-pratiṇipada', by Varāhamihira (otherwise, by no other method the Caitra-sūtra-pratiṇipada of Saka 427, can be shown to fall on Tuesday), and it was no doubt correct that the 'ahargana' is required to be calculated from that day. Varāhamihira appears to have adopted this epoch, because it is convenient to calculate positions from those on the 1st day of the light half. It is a well known fact of mathematical astronomy that the 'ahargana' calculated with the help of any 'Karāṇa work' proves to be correct within a day, and it has to be verified with the help of the day of the week. It may now be questioned as to why the Vaiśākha sūtra-pratiṇipada could have been called the Caitra-sūtra-pratiṇipada by Varāha. I have absolutely no doubt that the sūtra-pratiṇipada following the day for which the kṣepakas are given is the first day of the Vaiśākha-sūtra-halfmonth of Saka 427 according to the 'amānta' system. The Caitra is

defined as that ending lunar month which ends while the sun is in Mēṣa (Aries)-As the sun is found to be in Mēṣa at the end of that amāvāsya which fell on the day, next to the day for which the elements have been given irrespective of whether a mean or a true Mēṣa was reckoned; and hence, according to the above definition the amānta lunar month which ended with the amāvāsya must be termed as Caitra, and Vaiśākha commenced on Tuesday i.e. the next day. But a lunar month belonging to the pūrṇimānta system ends on the full moon day, and hence, the full moon day belonging to that half which commenced just after the 'kṣepaka' day will coincide with the end of the lunar month. The calculations made on the basis of 'kṣepakas' given by Pāṇcasiddhāntikā show that the sun still occupied the Mēṣa sign, and hence that lunar month naturally received Caitra as its name. The author does not find any other convincing theory to explain how that month could be termed Caitra. The pūrṇimānta system has remained in vogue in Northern India from a very ancient time. Even though the 'pūrṇimānta' system is still in vogue there, the lunar months are not named according to the system described above; but it appears that the system must have been in use in its pure form at the time of Varāhamihira.

The first couplet of the 8th Chapter gives the method of finding the sun's place according to the Romaka Siddhānta:—

सकस्यै शुभ्रात् सति (१५०) सात् पक्षे (१५) परिहीते ॥  
सप्तदशसप्तति ५४८७९ इति सप्तमः सः ॥

"Multiply the ahaṅgā by 150, deduct 65, and divide the remainder by 54787; the result is the mean longitude of the sun".

The sun's position is obtained by multiplying the ahaṅgā by 150, subtracting 65 from the product and by dividing the remainder by 54787. The figure denoting the sun's longitude is obtained in terms of bhagānas etc. (the bhagāna means a complete sidereal revolution of a planet through the Zodiac.) There is no doubt about this, although it is not explicit in the couplet. The sun makes 150 complete revolutions in 54787 days and hence, one revolution requires exactly 365 days 14 ghatis 48 palas. This is, therefore, the measure of a year according to Romaka. The modern Sūrya-Siddhānta gives 365d 15g 31p 31.4v. as the measure. Brahmagupta has blamed Romaka for not giving measures of yuga and other units, as is done by other Siddhāntas and the following discussion will show that it is true. In order to facilitate the comparison of Romaka with other Siddhāntas, below the figures are given indicating the number of revolutions and other measures relating to the moon in one Mahāyuga i.e., in 4320000 years, which are derived from the elements given by Romaka. The couplets from the Pāṇcasiddhāntikā on the basis of which these have been calculated are as follows:—

सकस्यै शुभ्रात् सति (१५०) सात् पक्षे (१५) परिहीते ॥  
सप्तदशसप्तति ५४८७९ इति सप्तमः सः ॥

"Romaka's yuga consisted of 2850 years. During this period, the number

of intercalary months is 1050 and that of pralaya's or suppressed tithis is 16547".

शुक्रं (१०) + चतुर्विंशत्यस्य (६०) = चतुर्विंशत्यस्य ॥  
 चतुर्विंशत्यस्य (३०) + शतं (१००) = शतं ॥ ५ ॥  
 शतं (१००) + शतं (१००) = शतं ॥ ५ ॥  
 शतं (१००) + शतं (१००) = शतं ॥ ५ ॥

"(5) Multiply the ahargana by 110, add 609, and divide by 3031; the quotient gives the position of the moon's *kendra* at *Sunset at Avanti*.

(8) Multiply the ahargana by 24, add 56266 and divide by 16311; the result is the successive position (in revolutions, signs, etc.) of Rāhu (i.e. the moon's ascending node), reckoning backwards from the end of Pisces (i.e. the first point of Aries). (24 revolutions of Rāhu are supposed to take place in 16311 sāvanadays)".

The following figures denoting several astronomical measures are derived from these couplets and from the above couplet describing the calculation of the sun's position and that describing the calculation of ahargana.

Number giving		During one Mahayuga 4320000 years		During a yuga of 2850 years	
Revolutions of stars	1582185600	1043803	2850	1040953	38100
Revolutions of the Sun	4320000	1040953	2850	1040953	38100
Savana days	1577865600	1040953	2850	1040953	38100
Revolutions of the Moon	57751578	13708	228	322	3031
Revolutions of the Moon's apogee	488258	57589	3031	26889	153
Revolutions of Moon's ascending node	232165	163111	163111	34200	1050
Solar Months	51840000	1591578	1050	35250	1057500
Intercalary Months	1591578	1050	35250	1057500	16547
Lunar Months	53431578	1602947368	1057500	16547	
Tithis	1602947368	16547			
Suppressed Tithis	25081768	16547			

The numbers showing the revolutions of the moon etc. in one Mahayuga are not integral numbers. Hence, the sun and the moon, according to Ramanāya, will not, like other Siddhantas, come together in the beginning of the Kaliyuga.

or a Mahāyuga. Similarly, the number of Jura months is also not an integral number and the Romaka's yuga has been stated to consist of 2850 years. This shows that the Romaka Siddhānta has not followed the system of adopting 4320000 years as the measure for a Mahāyuga.

The couplet describing the method of calculating the moon's place is very incorrect. The author could not calculate the number of the moon's revolutions from it; these have been calculated by a different method.

The kṣepakas at the epoch of the Karapa work are found to be as follows :—

Sun	.	.	.	11°	29'	34"	23"	Moon's Kendra	.	2°	12'	19"	57"
Moon	.	.	.	11	29	18	50	Moon's ascending Node	.	7	25	49	3

The Kṣepakas are true for the moment of sunset at Ujjayini on Sunday the 14th Jura tithi of Caitra Kṛṣṇa, Saka 427 (i.e. 20th March 505 A.D.).

Hipparchus, the Greek astronomer, lived about 150 B.C. His figure for the length of the year exactly tallies with that of the Romaka (viz. 365d—14gh.—48pal.)

The work of Hipparchus is not available at present, but he had compiled tables for calculating the positions of the sun and the moon only and not for calculating the planets. Well known European astronomers say that the latter were compiled by Ptolemy on the basis of the principles of Hipparchus. They also admit that the principles of Greek astronomy had already reached India long before Ptolemy's time. The Romaka Siddhānta gives the calculations of only the sun and the moon, and its measure of the year is found in no other Siddhānta. It does not describe the universally accepted yuga system and its name. Romaka appears to be western. All these things go to show that the original Romaka Siddhānta was compiled on the lines of the work of Hipparchus, and it must have been compiled after 150 B.C. and before Ptolemy's time i.e. 150 A.D.

It has already been shown above that the Paitamaha and Vasishtha Siddhāntas were older than the Romaka. Similarly, it is thought that even the Surya Siddhānta and the Pulisa Siddhānta of the Pāncasiddhāntikā are more ancient than the Romaka; for, it is obvious from Brahmagupta's work, that the other four Siddhāntas were regarded with more veneration than the Romaka. He has nowhere blamed any of the four works. After the time of Brahmagupta, the Romaka Siddhānta appears to have gone quite out of use, both in its original form and the form in which it was recast by Śrīṣeṇa. Utpala has nowhere made references to the Romaka on any occasion in his discussion of planetary calculations in his commentary on the Bṛhatsaṃhitā, but he has cited the authority of the four Siddhāntas, viz. those by Pulisa, Surya, Arya-bhaṭai or by Brahmagupta. The original Romaka Siddhānta seems to have disappeared in its original form at the time of Utpala. The Romaka Siddhānta of the present day gives elements according to the modern Surya Siddhānta and not according to any other Siddhānta; and even this Romaka Siddhānta is not much known to any one now-a-days. This shows that the veneration which the other Siddhāntas, out of the group of five, enjoy, is due to their being much more ancient than the Romaka.

\*See Grant's History of Physical Astronomy [Introduction page (iii)] and page 439; similarly, see English translation of Surya Siddhānta, by Burgess, page 330.

One more important proof about the Romaka being more modern than the five Siddhantas is given below :

*Measures of the year according to different works on astronomy.*

Days Ghati Pala Vipala Prativipala

Vedānga Jyotiṣa	366	..	..	..	..
Pañcasiddhāntikā group :					
1 Pītāmaha Siddhānta	365	21	25	..	..
2 Vasiṣṭha Siddhānta	..	..	..	..	..
3 Pulīsa Siddhānta	365	15	30	..	..
4 Sūrya Siddhānta	365	15	31	30	..
5 Romaka Siddhānta	365	14	48	..	..
First Arya Siddhānta	365	15	31	15	..
Brahmagupta Siddhānta	365	15	30	22	30
(Modern group)					
Sūrya, Vasiṣṭha, Śākalya, Romaka and					
Soma Siddhāntas	365	15	31	31	24
Second Arya Siddhānta	365	15	31	17	6
Rajamrgaṅka	..	..	..	..	..
Karaṇa Kuttuhala etc.	365	15	31	17	17½

Out of these figures indicating the measure of the year, none except that of Romaka are found to be smaller than 365d—15gh—30p, and none, excepting that of the Vedānga Jyotiṣa and the Pītāmaha Siddhānta, greater than 365d—15gh—32p. In other words, leaving aside the case of Vedānga Jyotiṣa and Pītāmaha Siddhānta, none of the rest, except the Romaka, differ from one another by more than 2 palas. Had Romaka been older than the Pulīsa Siddhānta and the Saura Siddhānta of the Pañcasiddhāntikā, all of them would have taken the same year measure, as the Romaka or one with a slight variation, and they could not have strayed very far from the Romaka. This proves beyond doubt that the Pulīsa and Saura Siddhāntas were older than the Romaka. It seems beyond doubt that all the Siddhāntas of the Pañcasiddhāntikā belonged to a pre Saka period.

It is Dr. Thibaut's opinion that the Romaka and the Pulīsa Siddhāntas of the Pañcasiddhāntikā are "not more modern than 400 A.D." He means\* to say that these two were compiled about the year 400 A.D. and the other Siddhāntas of the Pañcasiddhāntikā group were also compiled about the same year. But the above discussion will show that his view is erroneous.

The figures showing the number of revolutions and other elements, as given in the Romaka Siddhānta, which is available at present, are given later on. A comparison of these figures with the foregoing ones will show that there is absolutely no similarity between them. This shows that the modern Romaka Siddhānta did not exist before Saka 427.

The question whether the modern Romaka Siddhānta is the same as that compiled by Sriṣeṇa and whether the modern Vasiṣṭha Siddhānta was compiled by Viṣṇucandra, will be discussed later on.

## PULISA SIDDHANTA

A large part of the Patcasiddhantika is devoted to the Pulisa Siddhanta. It is stated in the 10th couplet of the first Chapter that Romaka's 'ahargara' is very nearly equal to that of the Pulisa Siddhanta. Then follows the calculation of the place of the huminaries etc. and of the eclipses of the sun and the moon.

It has not at all been stated what the motions and places of Mars and other planets are according to the Pulisa Siddhanta; but the last couplet states that "the planets have thus been described according to the Pulisa Siddhanta" and which shows that about 16 'aryas' in the end mention something from Pulisa Siddhanta about their direct and retrograde motions, and the rise and set of planets.

The elements pertaining to the Pulisa Siddhanta are found to be as follows :

सूर्यः (१२०) वर्णितवर्षात् (३३) मयस्य वर्णितवर्षादुत्तरार्धः (४३८३१) ॥

हस्तो वर्णितवर्षात् मयः... ॥ १४ ॥

अस्त्यो वर्णितवर्षात् मयः (१४१) मयः ॥

मयः वर्णितवर्षात् मयस्य वर्णितवर्षात् ॥ ४१ ॥

वर्णितवर्षात् मयः वर्णितवर्षात् मयस्य वर्णितवर्षात् ॥ ४२ ॥

"(14) Multiply the ahargara by 120, deduct 33, and divide by 43831 the result is the mean longitude of the sun in due order. (41) Multiply the ahargara by 8 and divide the product by 151; the quotient indicates the degrees of Rahu (i.e. the moon's ascending node) to which as many minutes have to be added, as there are complete revolutions. (42) This is a stanza stating certain correction to be applied to the place of the moon's node as found according to the above rule. Apparently 25 minutes have to be deducted from that place. We do not know what is meant by "Vīśika-bhāga Rāho".

These couplets are found in the chapter following the one consisting of the first 25 āryas, and they form part of the passages attributed to the Pulisa Siddhanta. The elements derived from these āryas are as follows. —

The measure of the year	365d 15gh 30pal
Number of Savana days in one Mahāyuga	1577916000
No. of revolutions of Rahu	65703915
	232227
	6-946855
Period of Rahu's one revolution	6794d 41gh 18pal

This gives for the measure of the year a figure different from that of other Siddhantas. Similarly, the period of the revolution of Rahu (the moon's ascending node) is also somewhat different.

The Patcasiddhantika mentions other things from the Pulisa Siddhanta which include the question of true places of the sun and the moon. It describes the method of finding 'carakapadas' (groups of ascensional differences) from the 'palabha' (the noon shadow on equinoctial day), and calculating therefrom the length of the day; terrestrial longitudes too have been considered.

॥ श्रीगणेशाय नमः ॥ (३) : श्रीगणेशाय नमः ॥

The word mentions, as in Vedāṅga Jyotiṣa, dīnamānaviddhi, or the increase in the length of a day at the end of Udagayana as compared with that at the end of the Dakṣiṇāyana. According to the sayana almanac, the minimum and the maximum length of the day at Ujjayini are 26gh. 26pal. and 33gh. 34pal. respectively; that is, the difference between the two amounts to 7gh. 8p. According to the Grāhalāghava these values are 26gh. 21p. and 33gh. 39p. respectively and the difference is equal to 7gh. 18p. These have been calculated by assuming 5-8 as the palabhā for Ujjayini. Pandit Bapudēva śāstri gives in his almanac, the maximum length of the day at Vāraṇasī to be 33gh. 56p. and the minimum length as 26gh. 4HP. The difference between the two comes to be 7gh. 52p. This has been calculated on the basis of 5-40 as the palabhā at Vāraṇasī. Assuming this very value for Vāraṇasī, the Grāhalāghava calculation shows 8gh. 4pal. as the difference between the two lengths. Assuming 6-15 as the palabhā, one gets a difference of about 9 ghais on the basis of Pulisa's 'Carakhaṇḍa' as given by the Pāṇcasiddhāntikā.

अष्टाश्वत्थारोप्यदिवहेनः क्रमात् कृतदीना ॥ अथास्ते शालग्रामा अहर्निशं नन्दकम् ॥

[\*Footnote by the translator:—

Although the text quotes 'arṣaḥ' as the word, the manuscript, which I could see by the kind permission of the local Scindia Institute, gives the word "arṣaḥ", and the explanation therein shows that the Mahāyuga (which was rendered as the 'divine yuga', by the later astronomers) consisted of (4800+3600+2400+1200=12,000 years). According to the prevailing system, the year was of 4 kinds and consisted of 4 kinds of months, each of 30 days of the corresponding denomination].



1 DGO/69

"The semidiameters of planetary orbits in *yojanas* are given below :—  
689378 of *the Sun*, Venus and Mercury, 51566 of the Moon ; 1296642 of Mars,  
166231 of Mercury's aphelion ; 8176688 of Jupiter, 428088 of Venus's aphelion,  
20319541 of Saturn and 41362683 of the Zodiacal belt."

दशान्वयकृतमनोवर्षः (१२६६४२) क्षत्रियैः ॥  
क्षत्रियमन्युः (१६६२३१) क्षत्रियैः ॥  
अष्टकक्षत्रियमन्युः (४१६६६६) क्षत्रियैः ॥  
अष्टकक्षत्रियमन्युः (४२००००) क्षत्रियैः ॥  
एकान्वयकृतमन्युः (२०३१९५४१) क्षत्रियैः ॥  
त्रिषु रश्मिः (४१३६२६८३) क्षत्रियैः ॥

"Beyond darkness has been created by God *Brahma*, this earth, round like wheel, was made up of five main elements. In its centre stands the mountain *Meru*, the abode of gods, and the pole occupies a place in the sky just above it. The wheel of stars, being propelled by wind, and creating rises and sets, revolves, as if pulled by 'reins' of wind. (The words 'na dwardwan' are not clear). All planets when occupying the north give success and only Venus, when in the south gives success."

Although the *Pañcasiddhāntikā* does not explicitly state that the *Puliśa Siddhānta* in it postulated the *Yugādī* system, it appears from the couplets, which mention the intercalary months and suppressed *tithis*, that it did not postulate the *Yuga* system. Moreover *Brahmagupta* has blamed only *Romaka* on that account. This tends to show that the *Puliśa Siddhānta* of the *Pañca-siddhāntikā* did probably contain the description of the *yuga*-system. The *Puliśa*'s statement as quoted by *Utpala* includes it. The '*sāvana māna*' (i.e. civil measure) alluded to in the statement is termed as '*solar*' in other works, and the solar measures in the former are termed *sāvana* by the latter. The measures of '*bhagānas*' etc., as quoted by *Utpala* from the *Puliśa Siddhānta*, taking the meanings of the words '*sāvana*' etc. as given by other works are given below :—

Revolutions of stars	1582237800
Revolutions of the sun	4320000
Sāvana days	1577917800
Revolutions of the moon	57753336
Revolutions of Moon's apogee (from <i>Beruṇi</i> )	488219
Revolutions of Moon's asc. node (from <i>Beruṇi</i> )	232226
Revolutions of Mars	2296824
Revolutions of Mercury's epicyle	17937000*
Revolutions of Jupiter	364220

\*This is the number of the planets' conjunctions with the Sun.

Revolutions of Venus's epicycle	7022388	.	.	.	.	.	.	.	.
Revolutions of Saturn	146564	.	.	.	.	.	.	.	.
Civil Months	51840000	.	.	.	.	.	.	.	.
Intercalary months	1593336	.	.	.	.	.	.	.	.
Lunar months	53433336	.	.	.	.	.	.	.	.
Tithis	1603000080	.	.	.	.	.	.	.	.
Suppressed days	25082280	.	.	.	.	.	.	.	.
The Length of a year	365 <sup>d</sup> -15 <sup>h</sup> -31 <sup>p</sup> -30 <sup>vp</sup>	.	.	.	.	.	.	.	.

This shows that the length of the year as given by the Pulisa Siddhanta of the Pañcasiddhāntikā and the Pulisa Siddhanta of Utpalā are different. This means that the Pulisa Siddhanta of the Pañcasiddhāntikā is quite different from the Pulisa Siddhanta of Utpalā. One more surprising fact is that Utpalā himself has given the sentence as an 'extract' from the original Pulisa Siddhanta:—

11 (0056622588) : 16/11/22 10:20 AM 16/11/22 10:20 AM

॥ : प्रपुष्पकः प्रपुष्पः प्रपुष्पः प्रपुष्पः ॥

“The number of revolutions of the stars in one Caturyuga (Mahayuga) is 1582237800.”

It gives the number of revolutions of nakṣatras in a Mahāyuga. This tallies with the one mentioned in the couplets quoted above. Even then, Utpala has mentioned this as a quotation from the original Pulīṣa Siddhānta, and it is composed in the Anuṣṭup meter. This shows that there existed at the time of Utpala (śaka 888) two Pulīṣa Siddhāntas which were different from the one belonging to the Pañcasiddhāntikā group. Hence, the number of Pulīṣa Siddhāntas comes to be three. The first two couplets of the last 2½, out of those quoted by Utpala, describes the Universe in the manner in which it is found described in the modern Śūrya Siddhānta and other Siddhāntas; the last half couplet refers to the conjunctions of planets. This shows that the Pulīṣa Siddhānta, composed in the Aryāmetre and existing in Utpala's time, must have been a complete work like other Siddhāntas. Similarly, the Pulīṣa Siddhānta belonging to the Pañcasiddhāntikā group also appears to have been a complete work from the detailed information cited from it above.

The numbers of revolutions and other elements in the Pulīṣa Siddhānta a quoted by Utpala, exactly tally with those of the Surya Siddhānta belonging to the Pañcasiddhāntikā and given on a subsequent page. Similarly, all the measures, excepting the number of civil days and the numbers depending upon it, such as suppressed tithis etc. and the revolutions of Mercury and Jupiter agree with those given by First Aryabhata.

Albiruni, the famous Muslim scholar and traveller, who had come to India with Mahmud of Ghazni, and stayed here from 1017 to 1030 A.D. and studied Indian sciences, particularly, the science of astronomy very critically remarks that the Pulisā-Siddhānta was compiled by Pāṇini or Pāṇini or Pāṇini, the Greek, which means that the Hindus compiled it with the help of his work. Weber says that Albiruni could get in India only the Brahmagupta and the Pulisā-Siddhāntas and none others.



3 k12345

Chapter 9—(1) According to the *Sūrya Siddhānta* the mean place of the sun is found (i.e. in revolutions and signs etc.) by multiplying the *śaraṅga* by 800, deducting 442, and dividing by 292207 successively; the place so found is for the midday at *Avanti*.

(3) Multiply the aharagana by 900, add 2260353, and divide by 2908789; the result is the place of the moon's *Ucca*.

(4) Multiply the revolutions of the moon by 51 and divide by 3120; deduct the result taken as seconds. Also, multiply the revolutions of the moon's *Ucca* by 10 and divide by 227; the resulting seconds are to be added to the moon's *Ucca*."

॥ १ ॥ ॥ २ ॥ ॥ ३ ॥ ॥ ४ ॥ ॥ ५ ॥ ॥ ६ ॥ ॥ ७ ॥ ॥ ८ ॥ ॥ ९ ॥ ॥ १० ॥ ॥ ११ ॥ ॥ १२ ॥ ॥ १३ ॥ ॥ १४ ॥ ॥ १५ ॥ ॥ १६ ॥ ॥ १७ ॥ ॥ १८ ॥ ॥ १९ ॥ ॥ २० ॥ ॥ २१ ॥ ॥ २२ ॥ ॥ २३ ॥ ॥ २४ ॥ ॥ २५ ॥ ॥ २६ ॥ ॥ २७ ॥ ॥ २८ ॥ ॥ २९ ॥ ॥ ३० ॥ ॥ ३१ ॥ ॥ ३२ ॥ ॥ ३३ ॥ ॥ ३४ ॥ ॥ ३५ ॥ ॥ ३६ ॥ ॥ ३७ ॥ ॥ ३८ ॥ ॥ ३९ ॥ ॥ ४० ॥ ॥ ४१ ॥ ॥ ४२ ॥ ॥ ४३ ॥ ॥ ४४ ॥ ॥ ४५ ॥ ॥ ४६ ॥ ॥ ४७ ॥ ॥ ४८ ॥ ॥ ४९ ॥ ॥ ५० ॥ ॥ ५१ ॥ ॥ ५२ ॥ ॥ ५३ ॥ ॥ ५४ ॥ ॥ ५५ ॥ ॥ ५६ ॥ ॥ ५७ ॥ ॥ ५८ ॥ ॥ ५९ ॥ ॥ ६० ॥ ॥ ६१ ॥ ॥ ६२ ॥ ॥ ६३ ॥ ॥ ६४ ॥ ॥ ६५ ॥ ॥ ६६ ॥ ॥ ६७ ॥ ॥ ६८ ॥ ॥ ६९ ॥ ॥ ७० ॥ ॥ ७१ ॥ ॥ ७२ ॥ ॥ ७३ ॥ ॥ ७४ ॥ ॥ ७५ ॥ ॥ ७६ ॥ ॥ ७७ ॥ ॥ ७८ ॥ ॥ ७९ ॥ ॥ ८० ॥ ॥ ८१ ॥ ॥ ८२ ॥ ॥ ८३ ॥ ॥ ८४ ॥ ॥ ८५ ॥ ॥ ८६ ॥ ॥ ८७ ॥ ॥ ८८ ॥ ॥ ८९ ॥ ॥ ९० ॥ ॥ ९१ ॥ ॥ ९२ ॥ ॥ ९३ ॥ ॥ ९४ ॥ ॥ ९५ ॥ ॥ ९६ ॥ ॥ ९७ ॥ ॥ ९८ ॥ ॥ ९९ ॥ ॥ १०० ॥

॥ ३ ॥ १ २ ३ ४ ५ ६ ७ ८ ९ १० ११ १२ १३ १४ १५ १६ १७ १८ १९ २० २१ २२ २३ २४ २५ २६ २७ २८ २९ ३० ३१ ३२ ३३ ३४ ३५ ३६ ३७ ३८ ३९ ४० ४१ ४२ ४३ ४४ ४५ ४६ ४७ ४८ ४९ ५० ५१ ५२ ५३ ५४ ५५ ५६ ५७ ५८ ५९ ६० ६१ ६२ ६३ ६४ ६५ ६६ ६७ ६८ ६९ ७० ७१ ७२ ७३ ७४ ७५ ७६ ७७ ७८ ७९ ८० ८१ ८२ ८३ ८४ ८५ ८६ ८७ ८८ ८९ ९० ९१ ९२ ९३ ९४ ९५ ९६ ९७ ९८ ९९ १००

“(1) The determination of the mean places of the smaller planets for midnight at *Avanti* is, according to the *Sūrya Siddhānta*, as follows:—Mercury and Venus have the same motion as the mean sun.

(3) For Saturn, multiply the aharṅa by 1000 and divide by 1076606. The quotients are the entire revolutions; from the remainders, the mean places of the planets are ascertained in signs, degrees and so on.

(5) Four signs, two degrees, twenty-eight minutes and forty-nine seconds have to be added to the mean place of Saturn.

(7) For the 'sighra' of Mercury, multiply the aharṅana by 100, and divide by 8797. Add the product of the completed revolutions, and four and a half 'aiparas'.

(9) Twenty eight degrees of Leo (i.e. 4 signs, plus 28 degrees) and seven teen minutes are the additive quantity for the 'sighra' of Mercury. From the 'sighra' of Venus 332961 seconds are to be deducted".

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of the yuga at midnight and that it postulates the Yuga system. These conclusions prove\* to be true from the fact that the figures for the revolutions of planets as given below agree with the planetary positions calculated on the assumption of the beginning of the Kali yuga at midnight.

The figures as calculated from the Couplets quoted above are as follows —

The length of the year . . . . . 365 — 15 — 31 — 30  
a gh pal vipal  
In a Mahayuga (i.e. 4320000 years)

The No. of revolutions of		The No. of revolutions of	
The stars	1582237800	Jupiter	364220
The Sun	4320000	Venus	7022388
Savana days	1577917800	Saturn	146564
Moon's revolutions	57753336	Solar months	51840000
Revolutions of Moon's apogee	488219	Intercalary months	1593336
Moon's asc. node	..	Lunar months	53433336
Revolutions of Mars	2296824	Tithis	1603000080
Revolutions of Mercury	17937000	Suppressed days	25082280

The epochal positions as 'emerging' from the above couplets (i.e. the positions at the epoch, calculated on the basis of the Surya-Siddhanta of Pāncasiddhāntikā) are as follows —

Sun	11	29	27	20
Moon	11	20	11	16
These positions are true for the noon of Sunday, the 14th of the dark half of Caitra, śaka 427 (elapsed).				
Moon's Apogee	9	9	44	53

\* Assuming at first that the yuga commenced on Thursday at midnight and adjusting planetary positions true for the moment, and then, arguing on the basis of the agreement of the two that the assumption was correct, appear like "arguing in a circle". But one is forced to follow this method in the case of many problems in astronomy when nothing certain is known about them in the beginning. I have stated above only the final results obtained after the full consideration of the facts embodied in the above couplets. But only experienced persons can realize what pains I must have had to take over before arriving at the conclusion, and in how many ways I had to make different assumptions and to attempt the verification of their truth. When in August 1887 and Feb. 1888, in spite of several difficulties enumerated below, I could establish a correspondence between the multipliers and divisors with the epochal elements, and could particularly explain how the planetary positions mentioned by the Bhīṣma-kāraṇa and Khanda-khādyaka almost agree with the figures given by the Surya-Siddhanta of the Pāncasiddhāntikā, and could establish a certainty about the three works, my delight knew no bounds. The difficulties were (i) the Pāncasiddhāntikā was compiled about 1400 years ago (ii) it had no commentary, (iii) the copy which I had obtained was very inaccurate, (iv) suspicion about the reliability of the words denoting the numerical quantities indicated by them and written below, in the above couplets, since the manuscript was incorrect, and (v) the fact that the figures indicating the length of the year and revolutions of planets do not fully agree with any of the modern Siddhantas. It must, however, be recorded here that this research does not deserve any more importance than what it is worth from the historical point of view. I enjoyed some more moments of delight while writing this work—The author.

The motion and position of Rahu (moon's asc. node) has been mentioned in the 5th couplet of the 9th Chapter, but the couplet is unintelligible. The first couplet of the 16th Chapter clearly states that the epochal positions are true for the midnight, but which day it refers to has not been mentioned. The positions of planets, calculated on the basis of planetary revolutions mentioned above and true for the midnight of Sunday, the 14th tithi of the dark-half of Caitra, i.e. a moment 3gh-9 palas before the mean Sun's entry into Aries, completely agree with the epochal positions given by the couplets. The 6th couplet gives the 'kṣepakas' (epochal positions) for Mars, and the figures for seconds (of arc) appear to have been left out from it. The 9th couplet mentions Mercury's positions which contain no figures for seconds; and the position of Venus is given shorter by four seconds. But there would be no harm if it be said that the difference of a few seconds in the epochal positions should be regarded as negligible.

The above mentioned figures denoting revolutions and the length of a year do not agree with the corresponding measures of revolutions etc. given by the modern Surya Siddhanta. This shows that the Surya Siddhanta of Pāṇcasiddhāntikā and the modern Surya Siddhanta differ from each other in respect of elements and revolutions etc. That the former is older than the latter is evident from the fact that Varāhamihira has incorporated only the former. The date of the latter will be considered later on.

The above figures from the Sūrya Siddhānta of the Pañcasiddhāntikā completely agree with those from the Pulīsa Siddhānta and cited from Utpalā above. It will be shown later on that Brahmagupta has adopted in his work, "Khaṇḍakhādyaḥ", all these elements except those for the Moon's Apogee and the Ascending Node. It will be seen that all the elements from the Sūrya Siddhānta of the Pañcasiddhāntikā, except those for the length of the year and the revolutions of Mercury and Jupiter, completely agree with those of the Siddhānta of Aryabhata which are given later on. It will be shown\*

\*Jupiter's 'Kṛepaka' (epochal position) as given by Bhāṣavalkaraṇa agrees with the calculated result, if 364224 be assumed as the Jupiter's bhāṣaṇas (revolutions) instead of 364220; but this (364220) can be proved to be the Jupiter's 'bhāṣaṇas' according to Pāṭa-  
siddhāntikā, from the multipliers and divisors, as mentioned in the first half of the 2nd couplet  
of the 16th Chapter, given above. Accepting 364224 as the correct number, 100 revolutions  
require 433227 days. Utpal's Pūṭīś Siddhānta and the modern Śūrya Siddhānta give  
364220 as the number of Jupiter's revolutions and on the basis of this very number one can  
arrive at the Jupiter's 'Kṛepaka' according to Kāṇḍakakāḍyaka. The Siddhānta of Aryabhaṭa  
states 364224 to be Jupiter's bhāṣaṇa; and Varāhamihira, while describing in the 8th  
chapter of Brhatsamhitā, the method of finding the 'Barhispātyasamvatsara' (Jovian year)  
for any śaka year, assumes a Kṛepaka which can be obtained by assuming 364224 as the  
Jupiter's bhāṣaṇa.

further, that the mean planetary positions for the epoch, have been obtained from the Bhāsvatikarāṇa, by borrowing from the Sūrya Siddhānta of Pāṇca-siddhāntikā, the elements for all planets, except Jupiter, and applying the corrections suggested by Varāhamihira separately, in the 10th and 11th couplets of the 16th Chapter of the Pāṇcasiddhāntikā.

Albiruni states that the Sūrya Siddhānta was compiled by Lāia; but, the Sūrya Siddhānta of the Pāṇcasiddhāntikā is not compiled by Lāia. Prof. Weber says† that the Sūrya Siddhānta must have some connection with Ptolemy. Both these points will be discussed later on in the course of the study of the modern Sūryasiddhānta.

The above study of the five Siddhāntas, includes that of their dates also. They are, Paitāmaha, Vasiṣṭha, Pauliṣa, Saura, and Romaka as seen in their chronological order. It seems that Romaka belongs to a pre Śaka period and the remaining four were older than it.

## THE PAURUṢA (HUMAN) AUTHORS OF ASTRONOMICAL WORKS BEFORE ŚAKA 420

The Pāṇcasiddhāntikā mentions names of some authors of astronomical works and no other source than this is available for obtaining any information about authors or writers of works before Śaka 420.

The following references are found in the Pāṇcasiddhāntikā—

पञ्चमहा श्रावणी (पौलिशोऽथकसिद्धांती) आरभ्याती श्रावणे ॥ ३ ॥

श्र० १.

श्रावणीश्रावणी यवपुरे श्रावणे सुप ॥ रघुदेव श्रावणी सिद्धांताय दिनांशानिर्दिष्टः ॥ ४४ ॥  
यवपुरे श्रावणीश्रावणी यवपुरे श्रावणे सुप ॥ रघुदेव श्रावणी सिद्धांताय दिनांशानिर्दिष्टः ॥ ४४ ॥

४५ ॥

सुपः स एव सुपदिश्यात् यवपुरे श्रावणी ॥

श्र० १२.

(3) The first two of the five (viz. Pauliṣa and Romaka) have been described by Lāiaadeva.

(44 & 45) The purport of these very important lines from the 14th chapter is as follows—Lāiaācārya has enjoined the calculation of aharāṇa from the moment of sunset (on the horizon) of Yavanapur.

(The moment of sunset at Yavanapur coincides with that of midnight at Lankā). Simhacārya has enjoined the calculation of aharāṇa from the sunrise at Lankā, while his preceptor enjoins the adoption of ten muhurtas (i.e. 20 ghatis) in the night for the calculation of aharāṇa in the Yavana country. Aryabhata after stating the commencement of the day as from the midnight at Lankā, has again defined the day as beginning from the sunrise\* there. The name of Simha's preceptor referred to here is not known. Here is a reference quoting some more names :—

† See Dr. Kern's Preface to the Bṛhatasamhitā and page 2 of the Translation of the Sūrya Siddhānta by Burgess.

\* Aryabhata's reference of the commencement of a day at sunrise at Lankā will be given later on. The reference of the day commencing at midnight in Lankā is not found in the Aryabhatiya.

11/29/2012

These are the names mentioned by the *Pañcasiddhāntikā*. Of these, an account of *Āryabhaṭa* will be given later on. All these names occur in *Brahma-guṇya*'s *Siddhānta* also. All of them have been criticised by *Brahma-guṇya* in some way or other. We do not come across any mention of their merits. The statement that *Śriṣeṇa* has adopted some elements from *Lāṭā* in his work, *Romaka*, has already been given above. *Varāha* remarks that *Lāṭā* has commented upon the *Puliśa* and *Romaka* *Siddhāntas* and this commentary cannot possibly contain his own views. This shows that *Lāṭā* must have compiled a separate work. *Brahmaguṇya* elsewhere observes :—

11.32

11 5X

It shows that *Laiācārya* had perhaps compiled a work. Similarly *Simhacārya* also had compiled one. Even *Varāhamihira* has remarked in one of the above mentioned couplets that *Pradyumna* broke down in respect of Mars and *Vijayanandi* about Jupiter and Saturn. The '*Karāṇa*' works of both these authors are described as '*padakaraṇa*'. In one of the couplets given before, *Brahmagupta* says that *Sūrya* has borrowed the '*Vijayanandi*'s *padas*. This remark is unintelligible, and it is not clear if '*pāda*' means a '*yugapada*'.

THE FIVE MODERN SIDDHĀNTAS

The Pañcasiddhāntikā included all the siddhāntas excepting the Somaśiddhānta, and it has already been shown that these siddhāntas and those which are to be considered now, are different, and this fact will be further corroborated by the discussion which will follow. The siddhāntas whose study is going to be made now are extant present and are different from those belonging to the Pañcasiddhāntikā group; and that is why the epithet 'modern' has been applied to them. Although there is no definite evidence to show that there existed or still exist two Somaśiddhāntas, still it is completely

12. The word "admitti" also seems to be a proper noun.

\*After studying the contents of Vdanga Jyotisa and the above discussion, it will be seen that there is no sense in the suspicion expressed by Weber that Lata must be the same as Lagadha.

similar to the other four, and it is desirable to study it (i.e. Somasiddhanta) along with them. After a general discussion of the five siddhantas, each of them will be considered separately later on.

#### APAVRUGEYA i.e. DIVINE

All the five siddhantas declare themselves to be divine and they are actually so regarded. No other siddhanta is regarded as divine except these five siddhantas, and some or all of the siddhantas from Pañcasiddhāntikā, and Viṣṇudharmottara Brahmasiddhanta. Even if there were some other siddhantas regarded as divine before, they are not at present available. The Vyāsasiddhanta, Garga siddhanta, Nārada siddhanta and Parāśara siddhanta are also divine; but these should better be called Sāṃhitās than Siddhantas. The author does not think that a work known after Vyāsa and others, and dealing with subjects usually found in siddhanta and in their usual order can be available at present; and if there be one, he has neither seen nor read it. The number of revolutions and other elements are quoted by European scholars from the Parāśara Siddhanta; but these are given in one of the Chapter of second Aryasiddhanta as taken from Parāśarasiddhanta. The siddhanta as an independent work is not available. This point will be considered at greater length in the study of the second Aryasiddhanta. The Brahma-siddhanta by Viṣṇudharmottara (Purāṇ) will later on be discussed at greater length. The most ancient of the 'pauruṣa' (i.e. human) siddhantas is the first Aryasiddhanta. Its date is Śaka 421. All the siddhantas enumerated at the top may not necessarily be more ancient than this. It is, however, felt that at least one of them must be older than that. Because all are similar to one another, and because these are also regarded as divine, it will be proper to describe them first, just after the discussion of Pañcasiddhāntikā.

At first the numbers of revolutions and other elements mentioned by all the five siddhantas, which are the same in all the works, are given below:—

The elements given by the Śūrya, Soma, Vasiṣṭha, Romaka Siddhantas and Śakalya's Brahma Siddhantas:—

Years spent in Creation	Number	In a Mahayuga
17064000		
	Revolutions of 'stars'	1582237828
	Revolutions of the Sun	4320000
	Savana days	1577917828
	Revolutions of the Moon	57753336
	Moon's apogee	488203
	Moon's anomaly	57265133
	Moon's node	232238
	Mars	2296832
	Mercury	17937060
	Jupiter	364220
	Venus	7022376

[illegible][illegible]

Node	Aphelion	Sun	Mars	Mercury	Jupiter	Venus	Saturn
..	387	.	.	.	.	.	.
214	204	.	.	.	.	.	.
488	368	.	.	.	.	.	.
174	900	.	.	.	.	.	.
903	535	.	.	.	.	.	.
60	39	.	.	.	.	.	.

## THE YUGA SYSTEM

These give 17064000 as the number of years elapsed after Creation, and some thing must be stated about this. Some idea about the yuga system has already been given in the Introduction. According to Brahmagupta and his followers, the creation took place at the beginning of Brahma's day, and at that moment, i.e. in the beginning of Kalpa, all the planets, their apheha and nodes were conjoined together with the first point of Aries. According to Modern Suryasiddhanta and other siddhantas which follow it, the world was not created at the beginning of Kalpa but Brahma required 47400 divine years that is a period equivalent to  $39\frac{1}{2}$  Kali yugas for creating the world. All planets, their apheha and nodes came together when so much time elapsed after the beginning of Kalpa, and then the planets began to move. Aryabhata II holds almost the same view. He, however, supposed a different number for the period elapsed in Creation, which will be mentioned later on. Similarly, the views of Aryabhata I, will be given later on. We have no means to know the views of Surya and other Siddhantas of the Pañcasiddhāntikā.

According to the modern Suryasiddhanta, all planets are supposed to come together by mean motion, in the beginning of the present Kaliyuga. Similarly, all the planets were together, at the end of the Kṛtayuga when the Sūrya-siddhanta was compiled. The numbers denoting revolutions of planets in a Mahayuga are divisible by 4. Hence, each planet makes complete revolutions in a period equivalent to  $2\frac{1}{2}$  (i.e.  $10 \div 4$ ) Kaliyugas, and therefore, all planets will come together after each such periods of  $2\frac{1}{2}$  Kaliyugas. A period equal to 4567 Kaliyugas passed after the beginning of Brahma's day till the beginning of the present Kaliyuga. This number is not divisible by  $2\frac{1}{2}$ ; hence, all the planets cannot be shown to be together at the beginning of Kalpa unless it be assumed that some years must have been spent in creation. Supposing

### GENERAL DESCRIPTION

It has no doubt been remarked above that the numbers of revolutions and other elements are the same in all the above mentioned five siddhāntas; but a slight departure was noticed which ought to be mentioned. A manuscript copy of the printed Vasiṣṭha Siddhānta is kept in the Deccan College collection (under No. 36—1870-71) and the following couplet is found in the first Chapter:—

first Chapter:—

"The number of revolutions of 'stars' in a westerly direction is 1582237516 in one Mahāyuga."

The number of savana days in a Mahayuga, as deduced from the number of revolutions of 'stars' mentioned in this couplet, prove to be 1577917516, which gives  $365^d 15^h 31^m 15^s \cdot 48^t$  as the length of the year. This measure is different from that of all other Siddhantas. But this verse is not found in the book printed in Vatanasi. Even the second version of Vasishtha Siddhanta referred to above (Deccan College collection, No. 78 of 1869-70) does not give the number of revolutions of stars. Again, the Siddhantas, which have been mentioned by Kamalakara (S. 1580), the author of Siddhanta-tatvaviveka as being quite similar to Suryasiddhanta include even this very Vasishtha-siddhanta. It appears from this that the couplet given in the Deccan College copy is interpolated, and that is why the numbers of revolutions and other elements in the Vasishthasiddhanta have been mentioned as bearing a resemblance with those of other Siddhantas.

The 8th letter is missing in this copy; there must have been some letter denoting the number 7, and hence, I have inserted "6" as the letter. See Chapter on "Chester's letter" page 65.

†See Chapter on "Baptismal Water" verse 65.

## THE DATE

Let us consider in a general way the dates of these five Siddhāntas.

Bentley has found out a method of determining the date of compilation of a work on astronomy and from it he has fixed 1091 A.D. or Saka 1013 as the date of the modern *Sūrya Siddhānta*. The method is as follows:—

To calculate the mean positions of planets with respect to the sun from the formulae given by the *siddhānta* whose date is to be found, and then after comparing them with the corresponding mean positions calculated from modern European books on astronomy, to see for what date, the planetary positions, as given by the *siddhānta* prove to be true in the case of each planet, and then to fix up the date of the *siddhānta* by adopting the average date. This method appears to be correct at first sight, and there can be no mistake if we accept Bentley's assumptions. But it is wrong to follow this method as can be seen from all considerations and the dates found out on that basis will not be reliable. The reasons are as follows:—Bentley's big mistake lies in the fact that he compared the mean places of planets calculated from the correct European tables, with those obtained from the Hindu astronomical works. But the mean planets cannot be seen in the heavens; what is meant is that the planets will be seen to occupy those positions in the heavens which are found as true longitudes and not as mean. Whenever the Indian astro-nomers compiled their original works or found that the planets did not occupy places as indicated by their original works, they rectified their original works by applying suitable corrections (*bijasaṃskāra*) as applicable at their time. They must have done this with the help of observed positions, i.e. the places which they saw the planets actually occupying in the sky. The difference between the mean and the true place of a planet may be termed as '*phalasaṃskāra*' (equation of centre). If the value of this '*phalasaṃskāra*' and the method of applying it be the same in the European and Hindu works, there would be no harm if the method of finding the date of a work on the basis of mean place be followed; but it is not so. The '*phalasaṃskāra*' to be given to the Sun is never less than  $2^{\circ} 10'$  according to any Indian work while that according to the European works it is about  $1^{\circ} 55'$  at present; and this equation is not always the same. The authors of European works have proved that this equation was  $2^{\circ} 10'$  at 3000 B.S. (before Saka), but is gradually decreasing. The Moon's equation according to the Hindu works is about  $5^{\circ}$ , while according to European works it some times comes to  $8^{\circ}$ . The equation adopted by the Hindus is very erroneous. Similarly, the methods of finding the true place from the mean place and the elements for the '*mandocca* and '*śigrocca*' (*aphelia*) are different in the two kinds of works. Hence, it should not be taken to be a rule that even if the mean longitudes of planets, as calculated from the Hindu as well as the European works agree, that will result in the same figure for the true place obtained conversely, it cannot be said that a similar figure for the true place obtained from both will not necessarily give the same figures for the mean longitudes. Similarly, whatever difference be found in the two will not be found to follow the same law for all times to come. If under a particular case, similar values

of mean longitudes calculated from the two, be seen to yield similar figures for the true longitudes as well, they will be found to give different value in another case. For instance, if the mean and true places of Saturn, in Leo, be found to be the same figures according to both the works, it is not certain that similar results will be obtained for the Saturn in Scorpio. Hence, the variation in values of the equation of centre and that in the methods of finding them, would be found to lead to a variation of some centuries, even when the variation in the values of equations as found from the two works be very small. For instance, the following errors were noticed in the planetary position according to the modern Surya Siddhanta in the years noted below and as found by Bentley:—

	538 A.D.	1091 A.D.	Correct	Year A.D.
Moon*	0	0	0	1097
Mars	0	0	0	1458
Jupiter	0	0	0	906
Saturn	0	0	0	887

This shows that the error in the place of Mars in 538 A.D. was about  $2\frac{1}{2}^{\circ}$  and in those of others less than  $2^{\circ}$ . The error in the case of the Moon was extremely small. The places of all planets can possibly be found to be the same as the true places calculated by European tables and true for some moment during some particular revolution of those times; that is, in other words, they can prove to be most accurate; and hence it can be said that if the places of planets given by the Surya Siddhanta agreed with those calculated from European tables for some date during the decade near about 538 A.D.; then the Surya Siddhanta can be said to have been compiled about the year 538 A.D. The compilation of original works of the Hindus or the corrections applied to them must have been based on the experience of at least 25 or 30 years; and there are no means to know which planets were observed, on what dates and how, during this period. Hence, the method of determining of the date of compilation of a work according to Bentley's method is not faultless. Prof. Whitney has pointed out some of the drawbacks of Bentley's method, but has not pointed out the above very important and main drawback.

Bentley himself has considered the pros and cons of this method, but has not considered these objections.

Another point is that Bentley, while comparing the places of planets, has only calculated their distances from the Sun, but has not considered the error in the Sun's place as given by the Indian works, and which has crept in because of a small error in the length of the sidereal year adopted by our works. Prof. Whitney has pointed out that the consideration of this point will show that the Sun's place given by the Surya Siddhanta would be for the year 250 A.D. The

\*When the planet's place is seen to be in advance of that obtained by European tables, the variation is indicated by plus (+) sign, and when it is behind, it is denoted by minus (—). The error in the case of Mercury and Venus exceeded  $3^{\circ}$  and hence, the difference has not been shown here.

†It is sure that if the positions of all planets be calculated from both the works for different dates during 5, 10 or perhaps 30 years, it can be shown that the planetary places do agree for a particular date; but the author has not done the calculation, since it involves much time and labour.

Indian authors could possibly have determined the corrections (Bijasarṃskāra)\* to be applied to planets by two methods. One method of determining the correction for a planet is by observing its conjunction with stars, and the second is by observing its place by the 'Nalika' instrument. The length of a year adopted by our works which is nearly equal to that of the sidereal year but actually exceeds it by about 8 palas and this (variation) leads to a gradually increasing error in the longitudes of stars. The error at present is about  $4\frac{1}{2}$  degrees. (The difference in the Paṭwardhan's almanac and other nirayana almanacs is due to this fact). Hence, if the corrections were determined from the conjunction of the planet with a star, it is bound to err, because the place of the star with which the planet was conjoined, was erroneous, and the date of compilation of work found on this basis must also err. The second method is that of observing a planet by the 'nalika' instrument. These methods of observation necessitate the conversion of the planet's place into a tropical (sāyana) form; and although the adopted motion for the equinox is somewhat erroneous, the correction is not likely to go very wrong because the time taken by a planet or the sun to come to equinox does not differ much. Hence, because the corrections have been determined by this method, the date of compilation of a work, as found by Bentley's method of comparison of errors in planetary places with respect to the sun, can be accepted; but the time when the sun, according to our works is found to come to the equinox, is somewhat erroneous. Because of this and also because the correction can possibly have been erroneous to the extent to which the observed results would be approximate, the date of compilation of a work can also be erroneous. The third point to consider is that, if it be supposed that Bentley's method is correct, it will be proper to use his method, if the author of the work, whose date is to be determined, has given the positions of planets by actual observation. But it will be of no use to apply the method, if the author has incorporated in his work the planet's places exactly as they are given in another work. If the correction given by Bhāskara in his work be set aside, the elements of revolution etc. given by him are exactly the same as those given by Brahmaguptasiddhanta, and hence, the date of compilation of both these works will, by Bentley's method, come to be the same; but the fact remains that Bhāskara compiled his work, "Siromani", 522 years after Brahmagupta's Siddhanta. The correction given by Bhāskara's work is found even in Rāja Miṅāṅka, a work of Saka 964. (More discussion about this will be given later on.) Hence, the dates of Rāja Miṅāṅka (Saka 964), Siddhanta Siromani (Saka 1072) or of Karaṇakutubha (S. 1105) will come to be the same by Bentley's method.

Bentley's method proves useless if the dates found by it are compared with the actual dates: The author attempted to apply the method in the case of the Surya Siddhanta of the Pañcasiddhāntikā and the first Aryasiddhāntikā and these are the inferences:—

\*If it is found that the place of a planet as calculated from a Siddhanta does not agree with the observed place, it is decided to apply suitable correction to the motion and place of the planet as given by the work and this correction is known as 'Bija'.

The year when the planet according to Suryasiddhanta would be correct

The year when the planet according to first Aryaiddhanta would be true

Saka	Saka
468	520
482	482
523	—
457	457
734	93
480	772
409	409
574	574
<hr/>	
$4127 \div 8 = 516$	$3307 \div 7 = 472$

This leads one to infer\* that the *Sūrya Siddhanta* of *Pāṇcasiddhāntikā* was compiled in Saka 472 and the first *Arya Siddhanta* in Saka 516. But it is beyond controversy that the first *Arya Siddhanta* was compiled in Saka 421 and it has also been shown before that the *Sūrya Siddhanta* of *Pāṇcasiddhāntikā* must have belonged to a period much earlier than Saka 421. Bentley has determined 1288 A. D. (Saka 1210) as the date of the *Arya Siddhanta* consisting of 18 chapters (i.e. the second *Arya Siddhanta*) and 1384 A. D. (Saka 1306) as that of the *Parāśara Siddhanta*; but reference to some subjects in the second *Arya Siddhanta* is found in the *Siddhanta Siromani*. This shows that the second *Arya Siddhanta* must belong to a period earlier than Saka 1072 A. D. and references to *Parāśara Siddhanta* also are found in the second *Arya Siddhanta*. (More discussion about this will follow later on.)

This will clearly show that the dates found by Bentley are not at all reliable and that the date of the *Sūrya Siddhanta* (viz. Saka 1013) determined by Bentley is not worth considering.

Let us, therefore, independently consider the matter of dates of the five *Siddhantas*.

*Brahmagupta* observes,

अथवा इति: सूर्यसिद्धान्तसिद्धान्तयोः ॥ ३ ॥

अथवा २२

"This very *Siddhanta* has been compiled by *Sūrya*, *Indu*, *Puliṣa*, *Romaṣa*, *Vasiṣṭha*, *Yavanaśācārya* and others".

The *Indu Siddhanta*, mentioned in this, is the *Soma Siddhanta* itself. It shows that there existed a *Soma Siddhanta* before the time of *Brahmagupta*. No evidence is available to show that there existed some time before, a *Soma Siddhanta*, different from the *Soma Siddhanta* now available. No such *Siddhanta* is either available at present, or there is no evidence of its availability. Where then is the harm, if we say that, in the absence of any evidence

\*Places of planets to be calculated from European tables have been calculated from the *Keropati's Planetary Tables*. If more accurate table would be followed, a variation of only 5 to 10 years may possibly occur.

See Bentley's work (1873 A.D.) Part II, Section III.

1 D.G.O. 69



time (principles of science of astronomy). God Madhusudana who is proud in this science, appreciating the good motives of Vasishtha and being pleased with them both, gave them away the science, as a reward for penance. He uttered the words of Science through the two mouths (Vasishtha and Romaka).

Even though these contain certain errors, the verses show that Romaka and Vasishtha are both associated with the modern Romaka Siddhanta. The Romaka Siddhanta existing at the time of Brahmagupta had definitely a support from Vasishtha (Siddhanta). Hence, an inference can be drawn that Sriṣeṇa's Romaka and Viṣṇucandra's Vasishtha, existing in the time of Brahmagupta, are the same as the modern Romaka and Vasishtha Siddhantas. The modern Romaka Siddhanta does not mention Sriṣeṇa's name and the name of the Siddhanta has been maintained, through an imaginary sage Romaka. It, therefore, seems probable that the modern Romaka may be different from Sriṣeṇa's Romaka in respect of its wording, still the revolutions and other elements must have been the same in both.

If it be admitted that there existed before Brahmagupta (Saka 550) Siddhantas which were either completely similar or similar in respect of the numbers of revolutions and other elements to the Soma, Romaka and Vasishtha etc. how can it be said that the modern Surya Siddhanta, which resembles these three in respect of elements and which is commanding a greater reverence and importance at present than these three could not have existed before Brahmagupta's time? The modern Surya Siddhanta or the Soma, Romaka and Vasishtha, have no similarity with respect to elements with the first Arya Siddhanta, which existed before Brahmagupta, and with any of the earlier five Siddhantas of the Pañcasiddhantika. It has already been shown above that Lācārya had compiled a work quite independently; and according to Brahmagupta's remarks, the figures for the mean places\* of all planets in Sriṣeṇa's Romaka and Viṣṇucandra's Vasishtha had been borrowed from Lācārya's work. It appears from this that it was only Lācārya's work which was similar to modern Soma, Vasishtha and Romaka, out of those, which existed before Brahmagupta's time. This fact, which emerges from the above considerations, when weighed together with Albiruni's statement that Surya Siddhanta was compiled by Lācārya, lead one to draw the definite conclusion that, the mean places of planets i.e. and the numbers of revolutions and other elements in the modern Surya Siddhanta, have been taken from Lācārya's works and Lācārya lived before Varāhamihira (Saka 427). Hence, it is the author's opinion that the elements in the modern Surya Siddhanta belong to a period prior to Saka 427. Even if the modern Surya Siddhanta is not supposed to have been compiled by Lācārya, the modern Soma, Romaka and Vasishtha Siddhantas definitely existed before Brahmagupta's time; and the modern Surya Siddhanta is much more revered and regarded as important than any of these three. This shows that the modern Surya Siddhanta existed before the three Siddhantas and hence, the date of its compilation cannot be later than the 5th century of Saka era.

Let us now consider the five Siddhantas separately and in greater details.

\*Cocherle interprets the words as "Mars and other planets were taken from Vasishtha" but considering all facts with reference to the context, I think that the lines should be interpreted in the very way in which I have rendered them.

## SURYA SIDDHANTA

*Subject Matter and Date*

The modern Surya Siddhanta has 14 Chapters. All of them together contain 500 verses in 'anusup' metre. The verses at the beginning, out of those which have given the numbers of revolutions and other elements etc. above, show that a person who was a "part of God Sun Himself" described by Sun's order, this Siddhanta to Maya, an Asura, at the end of the Kṛtāyuga. It means that 2164996 years elapsed after its revelation, till the beginning of Saka 1817.

An inference has been drawn above that the modern Surya Siddhanta was compiled by Lāta and hence, it must have existed in a period much earlier than Saka 427. It, however, seems that it had not received 'Surya Siddhanta' as the name at the time of Varāhamihira, because the Pāṇcasiddhāntikā contains only one Surya Siddhanta, and it is different from the modern one. A reference to the Surya Siddhanta has occurred at two places in Brahmagupta Siddhanta. The couplets have already been given before (See page 7). We have no reasons to say that there were two Surya Siddhantas at the time of Brahmagupta, and hence, it cannot be said for certain that in his time also, the modern Surya Siddhanta had received 'Surya Siddhanta' as its name; and even if it had, it clearly appears not to have received so much importance. Because he has taken in his work, Kṛtāpādhādyaka, elements, not from his own Siddhanta or from the first Āryasiddhanta or from the modern Surya Siddhanta but from the Surya Siddhanta of the Pāṇcasiddhāntikā. Hence it cannot be said for certain as to when the modern Surya Siddhanta received the name 'Surya Siddhanta or inspired a feeling of reverence.' There is, however, some room for drawing an inference.

Even if the modern Surya Siddhanta were compiled by Lāta, it is not probable that all the verses in it were compiled by him. Some or almost all the remaining verses in it, except those mentioning the elements in the chapter on mean places, might have been taken from the original Surya Siddhanta, that is, the one belonging to the Pāṇcasiddhāntikā group. Otherwise, if the Lāta's work be not in the same form, as the present Surya Siddhanta, some one else must have compiled the modern Surya Siddhanta, by borrowing number of revolutions and other elements from Lāta's work and the remaining verses from the original (ancient) Surya Siddhanta soon after the Pāṇcasiddhāntikā, and two or three centuries later, it must have been an object of reverence, when the traces of its authorship were lost and forgotten.

Brahmagupta remarks (see page 8) that the Romaka and Vasiṣṭha Siddhantas were compiled by adopting Āryabhaṭa's method of geocentric calculations of planets; but the main elements of degrees of epicycles (paradyapāsa) which are so necessary for the geocentric calculations as given by Surya, Romaka, and others, do not agree with those of Āryabhaṭa but with the original Surya Siddhanta in many respects. (See the elements given in the first chapter on 'true places' later on).

The inference which follows is that either Lāta or whosoever be the author of the Surya Siddhanta, he adopted only, different numbers for revolutions and other elements etc. but borrowed the remaining items from the original Surya Siddhanta or retained them, word for word, as given in the original Surya



With the Greeks.

*Ptolemy*

Weber says that according to Hindu inscriptions Turumaya was the name of king Ptolemaios<sup>7</sup> of Egypt. From this Asuramaya appears to have been a corruption of Turumaya, and Maya seems to be the Ptolemy\* himself who was the author of the *Almagest*. But it has already been pointed out that Ptolemy's work has no connection with the original Surya Siddhānta. Similarly, the numbers of revolutions and other elements of the modern Surya Siddhānta given above do not at all tally with those of Ptolemy. This clearly shows that Ptolemy has absolutely no connection with the modern Surya Siddhānta.

*A Relation between the two Śūrya Siddhāntas*

Utpala's commentary on the Bṛhatsaṃhitā quotes the following verses as belonging to the Śūrya Siddhānta :—

[illegible]

अथ पृथक् पृथक् ॥

"The sun illuminates half the disc (side) of the moon, even if it is occupying the lowest position (with respect to the sun); and the second half is never illuminated. The sun is a sphere of lustre. The planets, the stars and particles of water shine brightly when they are illuminated by the sun. The farther the moon goes away from the sun, while in a lower position, the greater portion of its disc becomes visible to (people on) the earth."

"While the sun is situated in the house opposite to that of the moon, having no latitude, enters that portion of the earth's shadow which intercepts the moon's orbit, the lunar eclipse takes place."

\*See page 3, Translation of the Surya Siddhanta by Burgess. The statement of Weber has not been given above word by word, but only its summarized form.

When the sun's surface is obstructed by the moon who is passing in a downward direction and when people on the earth are unable to see the sun, then the solar eclipse takes place.

The earth's shadow which is cast by the sun's rays, falls only on one half (Portion) of the moon's disc which is escaping from the darkness cast by Rāhu.

—Chapter 5 on Rāhu's motion.

These verses are not found in the modern Sūrya Siddhanta. It is not therefore, certain if they at all belonged to the original Sūrya-Siddhanta. If they did, it may be said that the modern Sūrya Siddhanta was not held in great reverence at the time of Bhatopala (Saka. 888).

Bhatopala, in the course of his discussion of Mahākārikādi Samvatsara in the chapter on gurutāra, in the commentary on Bṛhatsamhitā, observes.

कतिपयकालात् पूर्वम् च भवति यदा भवति तदा भवति

यदा भवति तदा भवति

"Some (astronomers) when they find that Jupiter has come to the star Kṛtikā, and Caitra has started, reckon the beginning of the cycle of Mahākārikādi years and also that of the prabhava year, on the basis of the star with which they find the moon to be conjoined."

The method of naming the years of the Mahākārikādi Series, as given in the modern Sūryasiddhanta, is as follows :—

यदा भवति तदा भवति यदा भवति तदा भवति

यदा भवति

.. In Vaisākha etc., a conjunction (yoga) in the dark half-month. (Kṛṣṇa on the 15th lunar day (tithi) determines, in like manner, the years Kārtika etc. of Jupiter, from its heliacal setting (asta) and rising (udaya).

Chapter on Elements.

These two have much similarity and this method of naming the Mahākārikādi years is found in no work other than the Sūrya Siddhanta. It cannot be known from the Pañcasiddhāntikā if this method was given in the original Sūrya Siddhanta and there is no other way to find it. If Bhatopala's quotation refers to the original Sūrya Siddhanta, it would be a good means to prove that the verses from the original Sūrya Siddhanta occur also in the modern Sūrya Siddhanta.

Lata

Albiruni, (Saka 952 circa) says that the Sūrya Siddhanta was compiled by Lata. But the original Sūrya Siddhanta in Pañcasiddhāntikā was undoubtedly not compiled by Lata, for had it been so, Varāha would have mentioned it and

Taberent readings are found in different works and the author himself is doubtful about the words "bimbasthorthe". We come across bimbasthorthe, bimbasthorthe etc. I have attempted to give the likely meaning.—Translator.

would not have included it in the *Paracasiddhāntika*. According to Brahmagupta, the work by Lāṭa is clearly different from the *Sūrya Siddhānta*. He has, in addition, criticised Lāṭa's work in two or three places, but not the *Sūrya Siddhānta*. This shows that the *Sūrya Siddhānta* referred to by Al-Bīrūnī as compiled by Lāṭa is not the original *Sūrya Siddhānta* but the modern one, and from this it appears that the importance of the *Sūrya Siddhānta* had been established before Śaka 952.

The author of *Bhāṣavālikarāṇa* declares at the outset of his work :—

अथ यद्यपि तद्विज्ञेयं । तद्विज्ञेयं यथा ॥ ३ ॥

अथवा २

"As instructed by Varāhamihira, I briefly compile this (*Karāṇa*) work which is similar to his *Sūrya Siddhānta*."

The words, "*raśmīyasiddhānta*" in this, show that there existed at the time of the author of *Bhāṣavāli*, a *Sūrya Siddhānta* different from the one incorporated by Varāhamihira in his work.

The following verses from the *Sūrya Siddhānta* have been given by Bhāskara-*racārya* himself in his commentary, *vaśana*, on *Siddhānta Siromaṇi* :—

अथवा १ ॥ अथवा १ ॥ अथवा १ ॥ अथवा १ ॥ अथवा १ ॥

"(1) Forms of Time of invisible shape, stationed in the *Zodiac* called the conjunction (*siṅhrocca*), apsis (*mandocca*) and node (*pāta*) are causes of the motion of the planets."

"(2) The planets, attached to these beings by cords of air, are drawn away by them, with the right and left hand, forward or backward, according to nearness, towards their own places."

These verses are given by the modern *Sūrya Siddhānta* (see verses 1 and 2 in the chapter on 'true place'). Similarly, Bhāskara-*racārya*, in the chapter on *Golabandha*, remarks about the motion of the equinox as follows :—

तद्वत्तः सित्तात् अन्ता अन्तात् ॥ १० ॥

"The point of intersection of the Equator and the Ecliptic, is called '*Kṛāṇ-*īpāta**'. The number of its revolutions in one kalpa, according to the *Sūrya Siddhānta* is 30000" and in his commentary of this verse, he himself says,

अथवा १ ॥ अथवा १ ॥ अथवा १ ॥

*Sūrya Siddhānta* itself has cited 30000 as the number of revolutions of the *kṛāṇīpāta* in one kalpa.

This remark refers to the revolution of the *Zodiac* mentioned in the modern *Sūrya Siddhānta*. Similarly the word '*arkāṇḍa*' occurring in Bhāskara-*racārya*'s remark "*tasmanmedam purvairarkāṇḍaistatā kṛāṇīpāta*" at the end of the chapter on 'solar eclipse' seems to refer to the modern *Sūrya Siddhānta*.

Meaning—This calculation has not been made by former astronomers like *Arkaṇḍa* (Incarnation of the Sun).

These arguments prove that the modern *Sūrya Siddhānta* had achieved the position of authority and reverence before the times of *Albīruṇī*, *Bhāṣyaṭikara* and *Bhāskara* i.e. before the first half of the 10th century of *Śaka* era. There is no evidence available at present to show what time it was between the *Śaka* 550 (i.e. the time of *Brahmagupta's Siddhānta*) and *Śaka* 950.

WORKS FOLLOWING MODERN SŪRYA SIDDHĀNTA

The *Karāṇa* work written in Saka 1220 by Vavilala Kōchana of Tālangana completely follows the modern *Sūrya Siddhānta*. It has not found any *Karāṇa* work written on the lines of the modern *Sūrya Siddhānta* prior to this date. The *Bhāṭīya* *śakaraṇa*, written in Saka 1339 gives the same motion for the equinoxes as that given by the modern *Sūrya Siddhānta*. A work called *Tājakaśāstra*, written in or about Saka 1445, has come to the notice. While describing the method of calculating the planets' places, it writes;

“The true places of planets can be calculated either by the method given by Śrīnaryatūya-Karaṇa work or by the one compiled by Rājamaṅḍaka.”

It shows that there existed before Saka 1445, a Karana work named *Surya-tulya*. The places of planets in it were, of course, taken from the *Surya Siddhanta*, and they must have been from the modern one itself. The figures for the length of the year etc. cited by 'Grahakautukakaraṇa' in Saka 1418 as having been taken from *Surya Siddhanta* belong to the modern *Surya Siddhanta*. Gaṇeśa Daivajña, the author of *Grahalaghava*, says

॥ ॐ नमो भगवते वासुदेवाय ॥

0 214611111111 0114 011

*Meaning* :—The elements for the sun, the moon's apogee and that for the moon diminished by 9' have been borrowed from the Surya Siddhanta.

And these elements have been definitely taken from the modern *Sūrya-Siddhanta*. Similarly, the tables of *Tilhi Cintamani* have been prepared completely from the positions of the Sun and other planets as given by the modern *Sūrya-Siddhanta*. (More discussion about this will appear later in the course of the comments on *Grāhalāghava*). A commentary on *Bhāṣawārikarāṇa* was written by *Mādhava* in *Saka* 1442, i.e. in the same year in which the *Grāhalāghava* was compiled. This commentary includes the verses, giving the revolutions of the sun, the moon, and all planets or the figures indicated in those verses. These verses and the numbers of revolutions and other elements, except those for *Rāhu*, completely agree with those of the modern *Sūrya-Siddhanta*.

*Makaranda* is the name of a work helpful in preparing the almanac. Almanacs are compiled from it in many parts of Northern India at present. The measure of the year and the numbers of revolutions and other elements for all planets have been taken by it from the modern *Singha Siddhanta*. The date of its compilation as given in the version of the *Makaranda* work, printed at Varanasi, is Saka 1400. This Saka number has not been stated in verse

form and no other means is available in the work to prove that it is true, which leaves some room for doubt about its authenticity. Makaranda is, however, referred to by Viṣṇuśiṅga and others which shows that the date may be correct. Paramādīśvara, the commentator on the *Āryabhaṭa* has given 12 verses\* from different chapters in the modern *Sūrya Siddhānta* and four of them, which are especially important, belong to the chapter on mean places, and they mention revolutions of the aphelia and nodes of all planets. The date of this *Paramādīśvara* is not known. The verses quoted by him from *Sūrya Siddhānta* are every where, preceded by the words "tathā ca Mayā" meaning "so says Mayā".

The work, *Tajikabhaṭṭa*, was written about Saka 1480, by Gaṇeśa Dāyaja, son of Dhunghirāja and resident of Parbharpur (Pāṭhār) near river Godāvarī. He has adopted in it the length of the year as given by the original S. S. The measure for the year (viz. 365d—15gh—31p—30v) as adopted by the original *Sūrya Siddhānta* appears to have been in continued use till the end of the 15th century, because it was more convenient for calculation than the one (365d—15gh—31p—31v—24pv) adopted by the modern *Sūrya Siddhānta*. There is a work on Mūhūrta, named *Jyotiṣadarpaṇa*, which was compiled in Saka 1479. It casually gives as an example, the ahaṛgaṇa (i.e. number of days elapsed) from the beginning of creation to the beginning of Kaliyuga. Similarly, the mean places of planets for the midnight of Thursday in the beginning of Kāpa have been given in it, and they are all similar to those of modern *Sūrya Siddhānta*.

There is a Kāraṇa-work, *Rāmavinda* by name, compiled in Saka 1512, which gives the length of the year according to modern *Sūrya Siddhānta*. *Kamalākara*, 1580, the author of the '*Siddhānta taravivēka*' is a staunch admirer of the modern *Sūrya Siddhānta*. The work *Vārṣikāntara*, which follows the modern *Sūrya Siddhānta* was written sometime between Saka 1400 and 1634.

#### Commentaries

A commentary on the modern *Sūrya Siddhānta* entitled '*Gūḍharīhapra kāsikā*' by Rāghanaṭha was written in Saka 1525. An edition of *Sūrya Siddhānta* together with this commentary, has been printed at Vārāṇasī and Calcutta. A second commentary, entitled *Saurabhāṣya* was written by Nṛsiṃha Dāyaja and belongs to Saka 1542. A third commentary was written by Viṣṇuśiṅga Dāyaja and entitled '*Gaṇarībhāṣya*'. It contains examples with solutions and belongs to about Saka 1550. A fourth commentary, written by Dādabhaṭ and entitled '*Kīraṇāvalī*' was written in Saka 1641. Of these four commentaries, that by Rāghanaṭha is more exhaustive and contains a good explanation of the theoretical aspect. Rāghanaṭha's commentary contains at 2 or 3 places the remark "एतत् विदितम्" meaning "this is according to tradition", and he has endorsed the views of others at 2 or 3 places with the remark "एतत् मतम्" meaning "according to some". At one place is found the statement "नक्षत्रं एतत्" meaning "modern people interpret it thus". This shows that some commentaries belonging to an earlier period were available in Rāghanaṭha's time. Rāghanaṭha has mentioned at four places, Parvata, as the name of some commentator, and has given a half-verse†

\*See verses 41 to 44 from *Madhyanāṭhikā*; No. 2 from *Pāṭhārīkā*, Nos. 35 to 40 from *Bhāṣya* and one from *Mādhikā*.  
 †See pages 156, 163, 201 of the Varanasi edition.  
 ‡See pages 48, 95, 147, Varanasi edition.  
 §See Varanasi edition page 201.  
 ¶See Varanasi edition page 212.

characterized as "गणितम्" (quoted from Nārmada). It shows that there must have existed some mathematical work of Nārmada in which some reference to or a corroborative statement of modern Surya Siddhānta could be found. In my opinion\* the date of this Nārmada must have been about Śaka 1300. Colebrooke says that there is a commentary on the Surya Siddhānta by Bhūdhara. Similarly, Prof. Whitney† remarks, on the basis of Wilson's catalogue, that commentaries on the whole or part of that work by Mallikārjuna, Yellayā, Aryabhata, Mammabhaia and Tammayā, were available in the Mackenzie's Collections. A commentary by any of the two Aryabhatas on any of the two Siddhāntas seems to be an impossibility. Hence, there appears to be a commentary by some third Aryabhata.

*Bibliotheca Indica* includes an English translation of the Surya-Siddhānta made in 1860 A. D. by Pandit Bāpūdeva Śāstri (New series No. 1). It contains simply the translation of the text and some notes here and there. The English translation of the Surya Siddhānta by the Rev. Ebenezer Burgess was published by the American Oriental Society as volume VI of its Journal in 1860; and it has been printed in a separate volume. It was Burgess who first translated the work and added foot notes to it and Prof. Whitney further added extensive notes on it. Prof. Whitney has admitted his responsibility about the views etc. expressed in these notes. It is the opinion of Prof. Whitney† that the Hindu borrowed astronomy from the Greeks. According to Burgess on the other hand it was the Greeks who borrowed astronomy from the Hindus and this view has been expressed by him at the end of the volume.

#### Interpolation

Rāṅganātha after giving a half-couplet in his note on the 23rd verse from the Chapter on 'conjunction of planets', has remarked that he has not commented upon the verse, since, it is found only in some works and not in all and appears to be interpolated. Similarly, after passing over 1½ couplet in the Chapter on 'elevation of moon's cusps' he has given his commentary in the next two verses and has remarked "but these appear to be disconnected and the method described therein is erroneous, they might have been interpolated by some very intelligent person who depended upon the "Dhivaddhidāntara of Lalla". He has also remarked that the four verses beginning from the 5th in the *Tripraśnadhikāra* might be regarded by some as interpolated, but it is not so; this shows that there were in his time some persons or commentators who regarded these verses as interpolated. *Jyotiṣadārpāṇa*, a work on Mubhūrta, contains about 19 verses from the chapters on mean places and on elements from the modern Surya Siddhānta which tally with those in the modern versions of the Surya Siddhānta; but there are 3 more verses, not given in the commentary by Rāṅganātha and inserted between some preceding and following verses from the original, and these do not appear contradictory to the context.

#### Diffusion

Out of the authors of *Kaṇva* and other works which have adopted the numbers of revolutions and other elements from the Surya Siddhānta and out of the commentators thereon described above, the author of the *Grahaṅghava* and Keśava, his father, belong to Kōṅkara and Mādhaba, the commentator of *Bhāskara* hails from Kānyakubja, that is, Kānaṇj. The

\*See the description of Nārmada, later on in this very chapter.  
†See Translation of the Surya Siddhānta by Burgess, page 278.  
††Prof. Whitney died in 1894.





in a particular period of time and their mean position at a particular moment; and *The third* is their true motions and true positions, by which is to be understood their position which is actually observed in the heavens, as being somewhat different from their position calculated from their mean motions, and the causes of this difference, the elements for finding out this difference at a particular time and the method of finding it; all problems (in astronomy) can thus be said to be included in these three types. That branch of astronomy which is known in English as Physical astronomy, is in the author's opinion to belong to the first type of the 'formation of the Universe.' The knowledge of astronomy concerning the second and third types, and specially the third, gradually develops with the growth of this (first) type. There is, however, no harm if it be said that no discoveries were made in our country, comparable with the several important discoveries that were made in the European astronomy after Copernicus. Hence, it can be said that the history of the formation of the 'Universe' does not hold an important position in the Hindu astronomy as it does in the European astronomy. All works have propounded almost the same views and no further discoveries have been made in them. It will, therefore, be better to describe all problems of the first type in one place. Some of them have been mentioned in the Introduction, and others will be treated later on. The problems belonging to the second type, being different for different Siddhāntas, have been described separately at their proper places; and some topics belonging to the third type will be given later in the study of the Universe, and the remaining in the chapter on true places; and these problems being the same in the case of each Siddhānta, it is better to mention them in one place in the chapter on true places. It will also be advantageous to indicate the differences between the Siddhāntas by comparison and this plan, when followed, will cover the study of all problems in the Siddhāntas. The numbers of revolutions and other elements etc. in the Siddhāntas of the Patcasiddhāntikā and in the five Siddhāntas of this chapter, have already been mentioned above. The mean positions of planets given in the Siddhāntas of the Patcasiddhāntikā have also been compared with those calculated from European works.

A comparison of mean planets given by the modern five Siddhāntas, including the Sūrya Siddhānta, with those calculated from the European works will be made in the description of Aryabhata later on.

### SOMA SIDDHĀNTA

#### The Date

This Siddhānta has been described by Candara to the sage Śaunaka. It mentions the number of years elapsed from creation up to the beginning of the present Kaliyuga and directs us to "add the desired number of years elapsed from the present Kaliyuga". This proves that this Siddhānta has been compiled in the Kaliyuga. The real date of its compilation is the same as that established for the modern Sūrya Siddhānta or one somewhat later than it.

It has 10 chapters and 335 verses in 'anusup' metre.

A work, entitled *Jyotiṣa Darpāṇa*, mentioned above, gives a verse from the *Soma Siddhānta*. The *Rāṅganātha's* commentary on the Sūrya Siddhānta gives at one place a verse from this (viz. *Soma Siddhānta*). *Kamalākara*, the author

[illegible]

• h h h h h h h h h h

अथ महिषवर्धन... अस्मिन्मन्त्रे ॥ अतस्तस्य मन्त्रोवा ॥ १८ ॥

These very verses occur in *Romaśa Siddhānta* also, as "quoted from Garga". The former half of the first verse in this runs thus.

The word Nanda occurs at one place in this Siddhanta. It has already been pointed out above that this Siddhanta resembles the Surya Siddhanta in all respects.

**Subject Matter**

It has already been pointed out above that there are two versions of Vasiṣṭha Siddhānta which are similar in principles but different only in form. Of these, the one, printed at Vārāṇasī, has five chapters, containing 94 verses in 'anugup' metre. It has been mentioned in the beginning and at the end that this Siddhānta was revealed by the sage Vasiṣṭha to the sage Māṇḍavya. This Siddhānta is very brief. Other Siddhāntas mention the numbers of revolutions and other elements in addition to the measures of orbital lengths also. This (siddhānta) gives only the orbital lengths and the numbers of the revolutions of planets in a Yuga have got to be calculated from them. These can be found and they agree with the Śūrya Siddhānta. This is also incomplete with respect to some other subjects. - This does not mention 'the number of 'savana' days in a yuga. It is not mentioned from what epoch the aharagana



Any reference to verses from this Siddhānta in any other work could not be detected.

**BRAHMASIDDHANTA CITED BY SAKALYA**

This has 6 chapters and 764 verses. This was described by God Brahma

**Subject Matter**

Date \_\_\_\_\_

The first chapter deals with the question who created the science of astronomy and contains the following verse,

"This (science) has been created (compiled) in eight ways, viz. by me, by Soma, Pulastya, Vivasvan (Surya), Romaka, Vasistha, Garga and Bharapeti. The word *matih* in this refers to this Siddhanta. Garga and Bharapeti have got only Sarghitas to their credit, while Siddhantas bearing the names of Soma, Pulastya, Surya, Romaka and Vasistha are well known. The Pulastya's Siddhanta is the same as Paulisa Siddhanta. It is referred to even by the name 'Paulisa' in this Siddhanta at two or three places. The following line occurs once in the first chapter:—

सूर्याय पश्य पश्यात्पश्यात्पश्यात् ॥ ६० ॥

"Hence the desired method should be followed as given by one of the five Siddhantas."

The names, Surya, Soma, Romaka and Pulisa, have also occurred at two or three other places. This clearly shows that this (Brahma) Siddhanta was compiled after all the above Siddhantas. It is very difficult to say in what particular period of time it was compiled; but the first chapter in this contains the line,

सूर्याय पश्य पश्य पश्य पश्य ॥ ६१ ॥

"The name of first year of Kalpa is Pramathi by solar measure."

Most of the works follow the method of reckoning the Prabhava and other years of the 60-year cycle on the basis of Jupiter's motion. It is only this Siddhanta, the Romaka Siddhanta and the commentary by Bhataopalala which refer to the adoption of the system, (of naming the year) by solar measure; and it is only in this Siddhanta, that according to solar measure, the name of the first year of Kalpa is Pramathi, and it will be found that the desired 'samvatsara' is always obtained on this basis by adding 12 to the Saka year (in question). At present, the samvatsara is not named by Barhaspatya system, south of Narmada, but by solar measure and thus we get the desired samvatsara by adding 12 to the Saka. But one year is suppressed in about 85 years if the Jovian measure is followed. Hence, we do not get the correct Jovian year by adding the same number to the Saka year every time. The figure to be added was shorter than 12 before Saka 743. The correct Jovian year used to be obtained by adding 12 between the period Saka 743 and 827. This figure is to be increased by one, after every 85 years. Copper plates and other inscriptions show that the system of finding a Barhaspatya (Jupiter's) samvatsara was the same in South India as in the North India till Saka 743; but the number 12 was required to be added between Saka 743 and 827. The author is of opinion that the system of reckoning a year by solar measure must have been adopted in South India from that period. A detailed consideration of this point will be made later on in the study of *samvatsara*. Because, this Siddhanta contains the method of finding a samvatsara by adding 12 to the current Saka, and states the first year of Kalpa to be Pramathi, there is no doubt that this Siddhanta must have been compiled some time after Saka 743 and not before.

It is the speciality of this work that it gives the latitudes and longitudes of the stars in Saptarsi group (i.e. Great Bear), which are not given by any other Siddhanta.

## FIRST ARYABHATA

Name

He has compiled the well known work *Aryabhatiya*. There is no other more ancient work from amongst the available 'pauruṣa' (human) astronomical works. He calls his work as *Aryabhatiya*, but many other astronomers have named it as *Aryasiddhanta* and it is quite proper to name it thus. A second *Aryabhatia* flourished after him and he has also written an *Aryasiddhanta*. It is, therefore, convenient to mention this *Aryabhatia* as *Aryabhatia I*, and his work as the First *Aryasiddhanta*, and the author has followed this principle all throughout.\*

This *Siddhanta* is divided into two main parts. The first part consists of 10 verses in the 'git' metre; and almost all the topics mentioned in the *Madhyamadhikara* of other *Siddhantas*; for instance, the elements of revolutions etc. in a particular period of time, have been mentioned in these 10 'gitis'. This part is called the 'dasagatika'.

The second part has three chapters, which contain the remaining questions mentioned in the other *Siddhantas*. It contains 108 *aryas* and hence, it is called the 'aryaṣṭasata'. Some people regard the two parts as separate works. *Sūryasafvana*, one of the commentators of this work, calls the two parts as two 'prabandhas' (compositions). Each of the two parts begins with a verse which is an auspicious prayer and hence, they might have been regarded by some as two separate works. But they are interdependent and one will be of no use without the other. It is, therefore, proper to regard the two together as one work. *Aryabhatia* himself appears to hold the same view. He has not given any separate name for the first part, nor has he closed it by a conclusion. He has no doubt added a 'conclusion' at the end of the whole work together and has mentioned *Aryabhatiya* as the name only at that place. Similarly, the whole work together has four chapters; the author himself does not call them as 'pādas', still it has been customary with others to call them so. If the 'Dasagatika' be supposed to be a separate work, it will be said to have one 'pāda' and the other work three and these cannot justly be called 'pādas' (fourth parts). Considering, therefore, from all points of view, it will be proper to regard the 'Dasagatika' and *Aryaṣṭasata* together as one *Siddhanta*. The *Dasagatika* contains two more 'gitis' in addition to the Ten; one of them is the auspicious prayer and the second describes his numerical code. The whole work, therefore, contains 120 verses. The word 'Aryaṣṭasata' is misleading, and it seems that because of this, some European scholars thought that it contained 800 verses. This *Aryasiddhanta*, along with the *Bhatadipika* commentary by *Paramādisvāra* has been recently printed by Dr. Kern at Leden in Holland in 1874. It was not much known to European scholars before this.

## Three Schools

The astronomical works in our country are at present believed to belong to one of the three main pakṣas or schools; the *Saurapakṣa*, the *Aryapakṣa* and the *Brahmapakṣa*. The basic work for the first school is the *Sūrya Siddhanta*, that for the second is the *Arya Siddhanta*, and that for the third is the *Brahma Siddhanta*. The reason for the formation of the three different schools is that the length of the year according to each school is somewhat

\*If any reference without the epithet 'first or second' occurs anywhere later on, it should be taken to refer to this, (the 1st) the first *Aryabhatia*.

The words *Aryasiddhanta* and *Aryapakṣa* are well known in our country but the *Aryasiddhanta* itself is not much known to anyone. It is considered that no orthodox astronomer in *Maharāṣṭra* possesses its copy. The *Aryapakṣa* (school) is still flourishing and it has a number of followers ; but very few of them understand its correct form from the original *Aryasiddhanta*.

Other astronomical works are found to be using 'bhū' for 1, 'tāma' for 3, and such other words to represent digits and numbers. But the First Arya-bhāṣya, instead of following this system has adopted letters to denote numbers, as shown below :—

Varāhamihira has followed in the Pañcasiddhāntikā the system adopted by other Siddhāntas while using words to denote numbers; and this shows that the system was in vogue before Aryabhata; and it must have been so. Hence, Aryabhata must have adopted it to represent numbers briefly and as it is not found in other works, it appears to have originated with him. This system ensures brevity. Other Siddhāntas generally require about 9 or 10 verses to mention the number of revolutions of all the planets. But it has been done only in two couplets by this system. Similarly, other Siddhāntas generally require 50 to 70 verses to be devoted to 'Madhyamaḍhikā'. This system could describe almost all the subjects in 10 verses (gītis) only; and hence, it is very easy to commit to memory the Daśagītika aphorisms written according to this system. But while this system has some advantages, it has at the same time a very serious drawback. To explain briefly the nature of the system and its inconvenience, an illustration is given below:—

The number of revolutions\* of 'Ku' (the earth), according to this verse comes to be 1582237500 in a Mahayuga.

\*Aryabhata holds the view that the earth has the diurnal motion and that is why he has given the number of rotations of the earth. Other Siddhantas give revolutions of stars instead.

Dr. Kern's book gives 'su' in place of 'bu' in this line. 'su' denotes 800000, that is, a number greater by 570000. The misprint of 'su' for 'bu' has caused so much error.

500	phi =
7000	si =
230000	bu =
1500000000	ni =
820000000	khst =

This is an error\* occurring in a printed book which is very carefully checked and printed; what then are the chances of errors having crept in in a manuscript and of these errors aggravated by traditional use, can be understood only by those who have occasions to go through manuscripts. Such a work is bound to go out of use in course of time, if there be no means like traditional interpretations, and checks of agreement with other works.

### Motions and Revolutions of Planets

After first quoting the two couplets which mention the numbers of revolutions and other elements of planets, the author gives the numbers derived from them. The first part of the first couplet has already been given above. The remaining couplets are given below:—

सप्तदशैव गोलार्धस्य कृत्वाक्षराणां गोलार्धस्य ॥ १ ॥  
 अक्षराणां गोलार्धस्य गोलार्धस्य गोलार्धस्य ॥  
 गोलार्धस्य गोलार्धस्य गोलार्धस्य गोलार्धस्य ॥ २ ॥

The revolutions in a *mahāyuga* as derived from these verses are:—

Rotations of the earth	1582237500	Revolutions of Jupiter	364224
Revolutions of the Sun	4320000	Revolutions of Venus	7022388
Number of sāvāna days	1577917500	Revolutions of Saturn	146564
Revolutions of the Moon	5753336	Solar months	51840000
Revolutions of the Moon's	488219	Intercalary months	1593336
Revolutions of the Moon's	232226	Lunar months	53433336
Revolutions of Mars	2296824	Tithis	1603000080
Revolutions of Mercury	17937020	Suppressed tithis	25082580

Length of the year=365d 15gh 31p 15vp.

The numbers of revolutions given by the original *Sūrya Siddhānta* on page 23, do not include those for Rāhu, but comparison of the remaining numbers with the above figures from the *Āryasiddhānta* shows that the revolutions of Jupiter and Mercury are different in the two, while the remaining numbers are the same; and it has already been shown before, that the original *Sūrya Siddhānta* existed before *Āryabhaṭa*. This shows that *Āryabhaṭa* borrowed the elements of all planets except those for Mercury and Jupiter from the original *Sūrya Siddhānta*. The elements for the revolutions of Jupiter and Mercury appear to have been adopted by him by experience after testing their accuracy with their observed positions.

\*This error cannot be detected from the commentary, but it can be easily found after considering the theory and agreement with other works. However, this error of Dr. Kern will throw several scholars into confusion.

*The Yuga System*

It has been remarked above that Aryabhata's system is somewhat different from that of the other Siddhantas. It is as follows. He says in his 'dasagatika':—

काली मय ६४ मयुगाश्च ७२ गतानि च मयुगखं २७ च ॥  
मयुगद्विगुणादा ग ३ च गुरुदिवसश्च मरतात् पूर्व ॥ ३ ॥

"The number of Manus in a Brahma's day is 'dha' (=14). A manu consists of akha (=72) yugas. The number of manus elapsed from the beginning of Kalpa is 'ca' (=6) and that of yugas elapsed is 'chna' (=27); and the number of yugapadas elapsed, prior to *Thursday*, the beginning day of Bhārata is 'ga' (=3)".

In this verse a Manu is said to consist of 72 yugas and not 71 as in others. A 'sandhi' (transition or twilight period) has not been mentioned as to occurring before the commencement of each 'manvantara'. This verse also tells us what period has elapsed from the commencement of Kalpa up to *Thursday*, the beginning day of Bhārata\*. This verse and the 2nd couplet quoted on pages 53, show that according to Aryabhata the Kaliyuga started on Friday, and the previous day was a Thursday. But the second couplet quoted above shows that the Mahāyuga\*\* began on Wednesday at sunrise. This shows that Aryabhata does not accept the definitions of time units, e.g. a Dvāpara equal to twice Kali, and so on. If these definitions be accepted, the Kaliyuga would not be found to have commenced on Friday, after supposing the yuga to begin on Wednesday. We get the result if all 'padas' or quarters of a yuga be supposed to be equal in length. This shows that he regarded Kita and other 'yugapadas' as equal in length, and from this assumption it appears that the number of years elapsed, from the commencement of Kalpa to that of the present Kaliyuga, comes to be 198612000 and the Kalpa appears to have commenced on Thursday. The number of years elapsed from the commencement of Kalpa to that of the present Kaliyuga comes to 1972944000† according to other Siddhantas; and according to some, who suppose that some years were spent at the beginning of the Kalpa or over Creation, it was a Sunday when the planets started to move. Brahmagupta has criticised† Aryabhata for having entertained this kind of view so different from others.

अथा युगचक्रः कल्पितो जगद्वर्तनः ॥ मयुगद्विगुणादा गतो जगति

मयुगति ॥ १० ॥

मयुग ति. अ. ११.

"The measures of Yuga, Manu, and Kalpa, and the number of Kita and other yugas elapsed after the commencement of the Kalpa, are not equal to those mentioned by the Smṛti. This shows that Aryabhata does not know mean motions of planets."

"The word 'Bhārata' stands for 'Bhārata war'. The word is here used in the sense of commencement of Kaliyuga."

\*\*Although the word mahāyuga has not been explicitly mentioned, it was evidently so, as may be seen from context and theory.

†After including the years supposed to have been spent over creation.

††Most of the above facts have been mentioned by Brahmagupta; but instead of placing implicit faith in them, I have actually found them out for myself.

In this verse, Aryabhata has been accused by Brahmagupta of not having given the Yugas, Manu and Kalpa according to the Smṛiti. The length of a mahāyuga adopted by him is equal to that given by others. The number of revolutions mentioned above will show that they are divisible by four, and the second couplet says that all the planets were together in the beginning of the mahāyuga. Similarly, according to Aryabhata the 'yugapādas' (i.e. parts of a mahāyuga) are all equal; and in his opinion the number of mahāyugas elapsed between the commencement of Kalpa up to the present Kṛta and other yugas is a whole number. Hence, according to his view, all planets come together at the commencement of each Kalpa, each mahāyuga and also at each Pāda or fourth part of a yuga. He has not at all given the number of revolutions of aphelia and nodes of other planets in a Kalpa. He had no reason to consider, if any years were spent over Creation; but in his opinion, all planets come together at the beginning of Kalpa. This shows that he did not at all make the assumption that some years were spent in Creation. If he were required to give the number of nodes and aphelia of planets he would have given them on the assumption that the beginning of a Kalpa coincided with the first start of the planets for their movement.

### Date

Aryabhata has recorded his date in the following couplet:

सहस्रवर्षात् सृष्टौ कालः प्रवृत्तः ॥

सृष्टौ कालः प्रवृत्तः सृष्टौ कालः ॥

कालः प्रवृत्तः

Aryabhata says that he was 23 when sixty 60-year cycles (i.e. 3600 years) had elapsed after the three 'yugapādas', that is, in the 3600th 'Kali-elapsed' year, which is the same as Saka 421. This shows that his birth year was Saka 398.

### Length of a Year

The length of the year according to the Surya Siddhanta of the Pāncasiddhāntikā is  $365^d-15^h-31^m-30^s$ , and that calculated from the elements given by Aryabhata above comes to be  $365^d-15^h-31^m-15^s$ , that is 15 vipalas less. But according to the original Surya Siddhānta of the Pāncasiddhāntikā, the Kali yuga commenced at midnight on Thursday; and Aryabhata has assumed it to begin it at sunrise on Friday, that is 15 ghatis later; but because the length of this year is less by 15 vipalas, the cumulative difference in 3600 years would be 15 ghatis less; and hence, the moment of the mean Sun's entry into Mēṣa i.e. the moment of the beginning of the elapsed year 3600 after Kali i.e. in Saka 421, according to the original Surya Siddhānta and Aryasiddhānta, comes to be the same; and this shows that he assumed the length of the year to be less by 15 vipalas in order to avoid the discrepancy which would occur, if the yuga be assumed to commence from the sunrise.

If anyone entertains any doubt about his date, the length of the year as given above will leave no room for such doubt. His date of birth is definitely Saka 398.

Place

Aryabhata observes in the first couplet of his 'Gaṇitapāda'

अथार्थकज्ञानं तद्विज्ञानं तद्विज्ञानं ॥

"Aryabhata, however, imparts the sacred knowledge in this (town of) Kusumapura."

From this, his place of residence seems to be Kusumapura, which is believed to be Patna in Bengal.

Subject Matter

The '*dasagatikāpāda*' of Aryabhata's Siddhānta contains the numbers of revolutions and other elements of planets. The next three pādas are devoted to 'gaṇita' (Mathematics), Kalakṛyā (time units) and 'Gola' (celestial sphere). The gaṇitapāda includes some subjects from arithmetic, algebra, geometry and trigonometry from among the branches of pure mathematics; and the remaining two pādas are devoted to astronomical questions alone. As a matter of fact, according to modern conception, astronomy is a branch of applied mathematics and hence, it need not deal with arithmetic and other branches of pure mathematics; but astronomy often requires the help of pure mathematics; and hence, it is natural for such ancient works to include both types; but such a combination is found in very few works. We have no means to know if it existed in the original Śūrya Siddhānta; but it is not found in the Pañcasiddhāntikā and also in modern Śūrya and Soma Siddhāntas. This Aryasiddhānta, the Brahmaguptasiddhānta and the second Aryasiddhānta, however, do contain pure mathematics also. Bhāskara's definition of a Siddhānta has been given above (page xxviii of part I), according to which he has included in the Siddhāntas both the branches of mathematics, viz. 'vyākṛti' or known (arithmetic) and 'avyākṛti' or unknown (algebra), and accordingly he calls his two works *Līlāvati* and *Bījagaṇita*, as parts of his work, *Siddhānta Śiromani*; still he has computed them as independent works; and some reference in it show that independent works on algebra were already compiled before Bhāskara's time. The two Aryabhatas and Brahmagupta have included algebra and other branches of mathematics in the Siddhānta itself; but these subjects have been treated in separate chapters.

The contents of the 'gaṇitapāda' will be briefly described in Aryabhata's work. This pāda consists of 32 couplets in addition to the benedictory verse-It contains the following subjects:—

Place names of digits of numbers, squares and cubes; square root and cube root; triangles, circles, and other figures and their areas; volumes of cubes and spheres; calculation of sines and their brief treatment; progressions, rule of three, fractions; an interesting type or two of problems solvable by rule of three or by algebra, and a section of mathematics known as 'kutṛaka' (problems of multipliers). These are the topics dealt with in the 'gaṇitapāda'. Ptolemy and the Greek astronomers before him had no knowledge of the sines. They used to make use of chords. The Europeans, before they studied Indian astronomy, held the view that it was Al Battani, the Arab astronomer (who lived in the latter half of the 9th century A.D.) first made use of sines in place

—: 0510A

॥ ०६ ॥

The approximate length of the circumference of a circle whose diameter is 2000 is 62000 increased by  $\frac{1}{104}$  multiplied by 8". This gives 62832 as the length of the circumference corresponding to 2000 as diameter, which gives 1:3.1416 as the ratio. Even this has been given by him as only approximate.

Arjabhata is the only astronomer in our country who holds that the earth rotates round itself; in other words, he holds that the earth has a diurnal motion. His remarks:—

**11. Unit 9**

"Just as one, sitting in a boat, observes stationary objects moving backwards; similarly, to an observer in Lanka (i.e. equator) the stationary stars appear to be moving towards the West".

[illegible]

But Aryabhata instead of giving the revolutions of stars in the list of elements has given the rotations of the earth. He has also remarked at another place (4th couplet of dasagūṭika) that the earth revolves through one minute of arc in a unit of time known as 'prāṇa' (i.e.  $\frac{1}{60}$  of a pala). Similarly, Brahmagupta and others have criticised Aryabhata for holding the view that the earth rotates. Brahmagupta says:—

11 ~~11/11/11~~ : 11/11/11

If it be assumed that the earth does rotate one minute arc in one 'Prana', unit of time, where, then, does it go and by what track, and how is it that objects situated as elevated places do not fall off?

Meaning.—The state, (when they take the place of a 'subject') observe the earthly objects (which become an 'object') as moving towards the east.



Aryabhata might have compiled some Karaṇa work. Aryabhata's conception of the day commencing with sunrise is given by the second couplet from Daśagītika given above (page 53); but Varāhamihira remarks that according to Aryabhata, the day is said to commence even from the midnight at Lankā (page 25). This statement of Aryabhata is not found in the Aryabhataiya, and even Brahmagupta is not seen to criticise him for this. It proves that even at the time of Brahmagupta, the Aryabhataiya did not contain some such couplets. Brahmagupta has referred to the two parts of Aryasiddhanta by these very words, viz. 'daśagītika and aryasāṣṭa'. From this it appears that no one has added anything to or taken away from the Aryasiddhanta which existed before Brahmagupta. The Varāhamihira's statement, therefore, suggests that Aryabhata must have compiled some other work, and Brahmagupta's Khaṇḍakhadyaka and Varuṇa's commentary on it, lead one to conjecture that there must have existed some Karaṇa work written by Aryabhata. It is, however, not available at present.

### Criticism

Brahmagupta has levelled a great deal of criticism against Aryabhata. After enumerating different points of criticism, he further remarks:—

रवयश्च सप्त सप्तम्यामृतं स्रुतं सप्तमिह ॥ स्रुतं तदस्रुतं च गणितं तत्  
सप्तमिह ॥ २२ ॥  
गणितकर्मणि यत् सप्तमिह गणितकर्मणि ॥ न यत् सप्तमिह ततः स्रुतं  
स्रुतं सप्तमिह  
॥ २३ ॥ अथ सप्तम्यामृतं स्रुतं सप्तमिह ॥ २४ ॥  
स. ग. वि. अ. ११.

"Aryabhata himself has claimed the correctness of his calculation; but that calculation has been proved to be incorrect on account of its disagreement with the actual phenomena of eclipses, etc. Since Aryabhata understands nothing of mathematics, celestial sphere or time, I have not mentioned separately his demerits concerning short-comings in respect of other subjects. It is impossible to enumerate all demerits of Aryabhata."

The fact that calculations of eclipses, etc., made from Aryabhata's works showed disagreement with the observed results is worth-considering. Their correctness or otherwise can be judged from some of the points of criticism enumerated above. Although it is true that some of the points are correct, still, Brahmagupta's statement betrays a great deal of prejudice.

### Loss of Works

Brahmagupta says:—

कालोत्तरं न तत्र स्रुतं: स्रुतं न ते सप्तमिह ॥

"I have not repeated the demerits which have been stated by others as time elapsed."

But, of the available works compiled before Brahmagupta, it is only the Pañcasiddhāntikā which mentions Aryabhata's name only, and makes no mention of any of his faults. This shows that some works of pre-Brahmagupta period must have been lost. The works of authors belonging to the period before Śaka 421 and mentioned above are not at present available.



"I have finally corrected" the 'Sun' from the yoga (conjunction) of the sun with the earth, the 'moon' from the conjunction of the moon and the sun; and all the 'planets' from the conjunctions of the moon and stars with the planets. I took out the jewel, in the form of true knowledge, through God's favour or with my own intellectual power, from the ocean of real and false knowledge."

Eclipses and conjunctions can lead us to find even the mean motions; but it is the true place which is chiefly found from them. This verse and the one referred to before this, will show that Aryabhata has made an improvement in the calculation of true places. Similarly, his high capability can be seen from the fact that he made researches by means of observation and intelligence after critically studying the old works with common sense.

#### ITS INFLUENCE AND FOLLOWERS

Utpala has extracted a number of couplets from Aryabhata in his commentary on Bīḥatsamhitā; and extracts from it are also found in a number of works compiled later on. Lalla, the famous astronomer, was a follower of Aryabhata. He has suggested a correction to the planetary motions given by Aryabhata. The Karāṇa work, named *Karāṇaprakāśa* which belonged to the Arya-Pakṣa and was compiled in Saka 1014, has been compiled after applying Lalla's corrections to the planetary places and motions obtained from the elements given by Aryabhata. (This will be explained in detail later on). Similarly, Dāmodara's Karāṇa work, named *Bhāṣiṇīya*, which was compiled in Saka 1339, follows the same method. Many people use *Karāṇaprakāśa* even now for calculation and many are its followers. The *Grahaṅghaṭa* has adopted the positions of Jupiter, Mars and Rāhu from the *Karāṇaprakāśa* and the *Grahaṅghaṭa* is followed in more than one third part of India.

#### PLACE

It shows that the Aryasiddhanta is even now followed, if not in its original form, at least with the application of corrections to it. Quotations from Aryasiddhanta are not found in astronomical works which were compiled in Mahāśāstra and Vātanasi after Saka 1400. It has already been pointed out above that the Aryasiddhanta is not available on our side in its original form. Dr. Kern has published an Aryabhata on the basis of three manuscripts obtained by him. All these manuscripts are written in the Malayalam script. This shows that the Aryasiddhanta is still known in South India and specially in the Malabar province. The provinces which speak the Tamil and Mala- yalam dialects follow the almanac computed on solar basis, and it belongs to the Aryapakṣa, since the year adopted in it is according to the first Arya- siddhanta. The Vaiṣṇavas are adherents of the Aryapakṣa. They form a large part of the population in Karnataka and Mysore. Patna in Bengal (at that time) is believed to be Aryabhata's place; but there is some doubt about it; because, the Aryasiddhanta is not at all in use in Bengal. It appears from this that the Kusumapura mentioned by Aryabhata might be some place in the south; nothing can be, however, said about it for certain.

#### PLANETARY CORRECTIONS

It has already been pointed out that the places of planets given by the Aryasiddhanta, sometimes tally exactly with those calculated from European tables; but for a clearer understanding and consideration of them, the mean positions of planets true for the mean Sun's entry into Aries of Saka 421 (i.e. 499 A.D.) as calculated from the *Aryabhata* and also from the European tables have been given together in a tabular form, on page 62-63

\*The first sentence refers to the lunar eclipse and the second to the solar eclipse.

Mean places of planets for 15 Ghaṭikās after sunrise on Sunday, Caitra Kṛṣṇa 9, Śaka 421.

Planets	Original Sūrya Siddhānta	Variation+ or—from column 12	First Ārya Siddhānta	Variation+ or—from column 12	Five Modern Sūrya & other Siddhāntas	Variation+ or—from column 12
	1	2	3	4	5	6
Sun	0	0	0	0	11 29 58 37	—0.1 23
Moon	9 10 48 0	—0 4 48	9 10 48 0	—0 4 48	9 10 29 33	—0 23 15
Moon's Apogee	1 5 42 0	—0 28 30	1 5 42 0	—0 28 30	1 0 53 51	—4 16 39
Rāhu			11 22 12 0	—0 42 18	11 18 36 4	—4 18 14
Mars	0 7 12 0	+0 7 0	0 7 12 0	+0 7 0	0 9 23 16	+2 18 16
Mercury	6 0 0 0	—3 22 12	6 6 0 0	—2 37 48	6 17 54 16	+14 32 4
Jupiter	6 6 0 0	—1 29 54	6 7 12 0	—0 17 54	6 5 59 53	—1 30 1
Venus	11 26 24 0	+0 6 24	11 26 24 0	+0 6 24	11 22 45 45	—3 31 51
Saturn	1 19 12 0	+0 51 54	1 19 12 0	+0 51 54	1 20 23 57	+2 3 51

Planets	Variation in Solar distance as compared with Col. 12	Brahmāgupta Siddhānta	Variation + or - from Col. 12	Variation in Solar distance as compared with Col. 12	Sāyana places calculated from Keropant's planetary tables	Nirayana places obtained from Col. 11 by applying ayān- āpasa correction of +16° 54'
	7	8	9	10	11	12
Sun . . . . .	0	0 0 51 45	+0 51 45	0	11 29 43 6	0 0 0 0
Moon . . . . .	-0 21 52	9 11 31 46	+0 38 58	-0 12 47	9 10 35 54	9 10 52 48
Moon's Apogee . . . . .	-4 15 16	1 7 21 3	+1 10 33	+0 18 48	1 5 53 36	1 6 10 30
Rahu . . . . .	-4 16 51	11 23 23 14	+0 28 56	-0 22 49	11 22 37 24	11 22 54 18
Mars . . . . .	+2 19 39	0 8 4 45	+0 59 45	+0 8 0	0 6 48 6	0 7 5 0
Mercury . . . . .	+14 33 27	6 0 41 2	-2 41 10	-3 32 51	6 3 5 18	6 3 22 12
Jupiter . . . . .	-1 28 38	6 7 28 9	-0 1 45	-0 53 30	6 7 13 0	6 7 29 54
Venus . . . . .	-3 30 28	11 26 57 12	+0 39 36	-0 12 9	11 26 0 42	11 26 17 36
Saturn . . . . .	+2 5 14	1 19 0 1	+0 39 55	-0 11 50	1 18 3 12	1 18 20 6

For a simultaneous comparison of all the works, the places of planets have been calculated from the original *Sūrya Siddhānta*, the modern *Sūrya Siddhānta*, and the *Brahma Siddhānta* for the same moment and have been noted in the same table.

*The moment of mean Sun's entry into Aries for the (elapsed year) Saka 421 works*

	gh. pal.	0	15	0	15	24	30
Original <i>Sūrya Siddhānta</i>		0	15	0	15	24	30
First <i>Ārya Siddhānta</i>		0	15	0	15	24	30
The modern five <i>Siddhāntas</i> ( <i>Sūrya</i> and others)		0	15	0	15	24	30
<i>Brahma Siddhānta</i> ( <i>Caitra Kṛṣṇa</i> 8, Saturday).		0	15	0	15	24	30

Time elapsed after mean sunrise at Ujjayini on Sunday, 9th lunar day of the dark half of 'amānta' *Caitra*, i.e. the 21st of March.

The 11th column on page 63 above, gives places of planets as calculated from *Keropant's* planetary tables; they are, therefore, as accurate as those calculated from European tables. They are *Sāyana*. Out of these, the secular equation is applied to the moon, the moon's apogee and the moon's node only. After applying the *ayanaṁśa* correction of 'plus 16'-54" in *Saka* 421 to the planets in this column, the *nirayana* positions so found have been given in the 12th column, and the places given by works, like the original *Sūrya Siddhānta* and others, have been compared with these figures. The precessional motion in 20 years comes to be 16'-54"; and taking this figure as the *ayanaṁśa* for *Saka* 421, therefore, is equivalent to taking zero as the *ayanaṁśa* for *Saka* 441. This year is very near to *Saka* 444. It is true that the equinox was near the junction-star of *Revati* about *Saka* 496, and it is suggested that the *ayanaṁśa* for that year should be taken as zero. But it has been pointed out thereafter in the study of the precession of equinoxes that the Indians were right in supposing *Saka* 445 as the zero-precession year according to their system. The object of assuming 16'-54" as the *ayanaṁśa*, while comparing the figures, is that it would facilitate the comparison with respect to the sun. It is not that there will be much error resulting from this. The error, at the most, would be four minutes of arc.

There is no harm if seconds of arc be neglected while making a comparisons since, they can be said to be carrying no value in the comparison. The sun's longitude as given in columns 1 and 3 is zero; and hence, the results of comparison of the planets' places in them with those of the 12th column which are noted in columns 2 and 4 are with respect to the planets and to the sun also, which means that the figures in columns 2 and 4 give the differences obtained by comparing the planets' positions independently with those given in column 12. Similarly, the figures in columns 2 and 4 indicate also the differences obtained by comparing the figures, showing positions of planets in column 12 ahead of the sun's position given in it and the figures indicating the advance of planetary positions in columns 1 and 3 over the positions of the sun given in them. The sun's longitude given in cols. 5 and 8, is not zero; and hence, the differences in the planets' places in these columns, as independently compared with those in the 12th column, have been shown in the 6th and 9th columns; and their differences, when compared with respect to the sun, have been given in the 7th and 10th columns.

The difference in the case of only *Revati* and *śrāvastī* out of other planets

given by the original *Sūrya-Siddhānta*, is greater than one degree, while that of others is less than that. Only Mercury, as given by First *Āryasiddhānta* differs by more than 2 degrees, while other planets do not differ by more than 51 minutes. Almost all the planets, except the moon, obtained from the modern *Sūrya-Siddhānta* differ by a considerable quantity. As for the differences in the positions of planets (with respect to the sun) in the case of *Brahmagupta*, *Siddhānta* and shown in column 10, that of Mercury only is really considerable, that of Jupiter is 53 minutes while that of others is less than 22 minutes of arc.

The whole discussion shows that there is no harm if it be said that the places of planets of all *Siddhāntas*, except those of modern *Sūrya Siddhānta*, for Saka 421, used to prove fairly correct. The position of the moon is no doubt given very accurately by all. All except *Brahmagupta*, have given the same number of revolutions for the moon; but the moon's place, as calculated from the modern *Sūrya Siddhānta* has come to be somewhat different from that of others because of different lengths adopted for a year. The discrepancy in the case of Mercury, according to all *Siddhāntas*, is considerable. The reason for this appears to be that its constant proximity to the sun allows rare chances for its observation.

The method of judging the accuracy or otherwise of astronomical works by comparing the mean places of planets as found from the European and Indian works has been shown to be not without risk in all cases and all circumstances, as explained in the course of the discussion of Bentley's method of determining the date of old works (page 30). But in the absence of any better way of judging how far our works agreed with observations in respect of the results of their calculations, the writer has followed the same method.

The numbers of revolutions and other elements mentioned by our different works have been given before and some more will be given later on. But, the periods of one sidereal revolution as found from European works and our works, have been given further (page 66) in order to facilitate the comparison of the two.

Ptolemy's measures given in it have been taken from the translation of the *Sūrya Siddhānta* by Burgess, and those for the *Sūrya Siddhānta* and *Brahma Siddhānta* (or *Siddhānta Siromani*) have also been adopted from the same book. There is, however, probably no error\* in them. The figures derived from the *Practical Astronomy* by *Loomis* have been adopted as the modern European measures.

The length of the year, as adopted by our *Sūrya Siddhānta*, when compared with that of the modern European works, appears to be greater by about 8 palas—34.5 vipalas and that of the *Brahma Siddhānta* by about 7 palas—25.6 vipalas. Even though the motion of the moon is considerable, there is almost no error in it. The time taken by the moon's node for one revolution is longer by 4 days and that in the case of Saturn is different by 6 days; the discrepancies in the case of others are less than a day.

#### PTOLEMY

Prof. Whitney observes that he has calculated Ptolemy's elements from the daily motions given by him, after taking into account the precessional motion (of 36" per year) as adopted by him. They do not at all resemble the elements given by our *Siddhāntas*. This proves that our *Siddhānta* works have not borrowed the places and motions of planets from Ptolemy's works.

\*Even if there be one, no calculation of the author given in this book has been made on the basis of these elements.

*Times required for one sidereal revolution*

Planets	Modern Sūrya Siddhānta			Brahmagupta Siddhānta			Ptolemy's work			Modern European works		
	Days	gh.	p. v.	Days	gh.	p. v.	Days	gh.	p. v.	Days	gh.	p. v.
Sun . . . . .	365	15	31 31.4	365	15	30 22.5	365	15	24 31.5	365	15	22 56.87
Moon . . . . .	27	19	18 1.6	27	19	18 0.25	27	19	18 0.2	27	19	17 58.866
Moon's apogee . . . . .	3232	5	37 13.6	3232	44	2 45	3232	24	40 34	3232	34	31 14.088
Meon's node . . . . .	6794	23	59 23.5	6792.	15	14 14.7	6799	58	16 38.5	6798	16	44 24.000
Mercury . . . . .	87	58	10 55.7	87	58	11 43.7	87	58	11 47.2	87	58	9 24.998
Venus . . . . .	224	41	54 50.6	224	41	52 34.7	224	42	9 52	224	42	2 47.486
Māra . . . . .	686	59	50 5.87	686	52	52 33.7	686	58	49 50.2	686	58	46 2.518
Jupiter . . . . .	4332	19	14 20.9	4332	14	24 19.2	4332	45	22 56.2	4332	35	5 17.49
Saturn . . . . .	10765	46	23 4.1	10765	48	54 51.2	10758	44	30 37.2	10759	13	10 57.49



*Aphelia and Nodes in Śaka 421 (l.e. Kali elapsed year 3600)*

Planets	First Ārya Siddhānta								Modern Śūrya Siddhānta								Brahmagupta Siddhānta							
	From Keropant's planetary tables				Variation from Keropant				Variation from Keropant				Variation from Keropant				Variation from Keropant				Variation from Keropant			
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
<i>Apsides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sun	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mars	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mercury	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Jupiter	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Venus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saturn	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Nodes</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mars	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mercury	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Jupiter	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Venus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saturn	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

## APHELIA &amp; NODES

The positions of aphelia and nodes of all planets according to different authors at the commencement of the Kalyuga and those for the year Saka 421 (i.e. Kali elapsed year 3600) have been given respectively in tables on pages 67 and 68. Prof. Whitney, after giving the aphelia and nodes according to Ptolemy and the Surya Siddhanta together, has suggested that the Hindus must have taken them either from Ptolemy or from other earlier Greek works. But the following comparative table shows that this statement is incorrect, as can be seen from the positions of aphelia and nodes according to Ptolemy and also the figures for the same for Ptolemy's time i.e. the year 148 A. D. (Saka year 70) as calculated from Keropant's planetary tables which give modern European figures.

A comparison of Ptolemy's figures for the Apsides and Nodes (in Saka 70) with those calculated from Keropant's tables :—

Planet	Ptolemy's work				Nodes			
	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place	(Sāyana) from Keropant's tables	Position	Diff. with Keropant's place		
							1	2
Sun	2 14 5	2 5 30	— 5 35				3	4
Mars	4 1 39	3 25 30	— 6 9	1 5 29	0 25 30	— 9 59	3	4
Mercury	7 18 32	6 10 0	— 38 32	0 26 5	0 10 0	— 16 5	2	3
Jupiter	5 15 7	5 11 0	— 4 7	2 22 1	1 21 0	— 31 1	2	3
Venus	9 16 18	1 25 0	— 231 18	2 0 39	1 25 0	— 5 39	2	3
Saturn	7 28 45	7 23 0	— 5 45	3 7 28	6 30 0	+ 85 32	2	3

The positions for apsides and nodes according to our old works (as shown on pages 67 and 68) at the commencement of Kalyuga and in the Kali elapsed year 3600 will show that the variation during 3600 years is very small; and the reason for this is their very slow motion. None of our Siddhantas mention the motion of the apsides and nodes as greater than 1 degree in 13000 years. The figures calculated from Keropant's tables and shown in the two tables above show that, if the equinox be taken to be the initial point, in other words, if the sāyana system be followed, the motion appears to be considerable; but the motions appear to be negligibly small if sidereal i.e. the nirayana basis be adopted.

The table on page 70, gives the annual motions of apsides and nodes very accurately calculated by modern European methods following the sāyana system and also the actual yearly motion\* according to the nirayana system.

\*These have been taken from Practical Astronomy by Loomis.

*Yearly motions of Apsides and Nodes.*

According to European Calculations					
Planets	Sayana	True Nirayana	That which must be adopted according to our Nirayana system	Surya-Siddhanta	According to the
	1	2	3	4	5
Aphelia . . . . .	Seconds	Seconds	Seconds	Seconds	Seconds
Sun . . . . .	+61.5	+11.24	+1.5	+0.1161	
Mars . . . . .	+65.7	+15.46	+5.7	+0.0612	
Mercury . . . . .	+56.1	+5.81	-3.9	+0.1104	
Jupiter . . . . .	+56.9	+6.65	-3.1	+0.27	
Venus . . . . .	+47.0	-3.24	-13.0	+0.1605	
Saturn . . . . .	+69.6	+19.31	+9.6	+0.0117	
Nodes . . . . .	.	.	.	.	.
Mars . . . . .	+25.0	-25.22	-35.0	-0.0642	
Mercury . . . . .	+40.2	-10.07	-19.8	-0.1464	
Jupiter . . . . .	+34.3	-15.90	-25.7	-0.0522	
Venus . . . . .	+29.7	-20.50	-30.3	-0.2709	
Saturn . . . . .	+30.7	-19.54	-29.3	-0.1986	

This motion has been calculated after assuming 50.2" as the equinoctial motion; but our works have assumed 60" as the equinoctial motion according to our works; and if the figures denoting motions according to European works are to be compared at all, they should be compared with this motion. Even when the comparison is so made, the motions according to the Surya Siddhanta are found to be very erroneous. The motions according to other Siddhantas can also be said to be equally erroneous. None of the other works gives for the annual motions of an aphelion or node, a figure greater than one third of a second. It is greater than 1 second according to the European system. It is very easy to criticise our works regarding this discrepancy, simply by seeing the figures on papers. But he who knows how difficult it is to observe an arc of one second in the sky even with the help of very accurate modern instruments will not blame them in that way. It has been observed by the author with naked eyes some conjunctions of planets with stars, and it has been our experience that those two planets etc. which are actually apart from each other by 5 minutes (300 seconds) of arc or more, as observed through a telescope appear to be in close contact with each other as seen with naked eyes, in other

words, there appears to be no distance between them. Hence, this fact should be borne in mind while comparing the figures of our works with accurate measures of European works and we must praise our works instead of condemning them regarding the apsides and nodes. We should appreciate the authors of our works, in as much as they recognized the fact that the motions of apsides and nodes are very small. It should only be seen as to how much accurate the longitudes of the apsides and nodes calculated from their works, prove to be. The positions of the apsides and nodes in Saka 421, have been given above (page 68) and their differences obtained after comparison with the figures calculated from Keropant's tables, have also been given. It shows that the positions given by our Siddhantas are very near to actual positions. Keropant-calculation gives sayana results, but since the ayanamsa in Saka 421 was about 20 minutes only, there is no harm in comparing the figures taking them as nirayana. The Sun's apogee, in fact, shows only a very little error; but the aphelion of Venus, however, shows a considerable error. Its cause is not known; it is a problem worth considering. But looking to the remaining aphelia, it appears that the aphelion of Mercury, according to First Aryabhata, is less by 24 degrees, while others differ within 10 degrees. Those of Surya Siddhanta are more accurate than these, that of Mercury being less by 13 degrees and that of Saturn less by 8 degrees. The aphelia of Mars and Jupiter show only a small difference. Those mentioned by Brahmagupta are as accurate as in the Surya Siddhanta or even more so. The table given on page 69 compares Ptolemy's aphelia with those derived by Keropant's calculation. These positions given by Ptolemy were presumably sayana like his other positions and the fact is corroborated from the positions of the sun's apogee and hence, there is no harm, if the figures are compared with Keropant's sayana calculations; and the comparison reveals that even his position of the aphelion of Venus is considerably wrong and his aphelia on the whole show greater errors than those in the Surya Siddhanta and Brahmagupta.

The nodes given on page 68 show an average error of 4° in Aryabhata's places. Those of the Surya Siddhanta are in error by 4°, those of Brahmagupta by 7° and those mentioned by Ptolemy (page 69) are erroneous by as many as 30 degrees. The nodes of Jupiter and Saturn given by him are considerably wrong. The position of the sun's apogee as given by him is 65° 30'. The sayana position of the sun's apogee in his time i.e. about 150 A.D. comes to be 71°. By no other method can one possibly get 65° 30' as its position. None of our Siddhantas show an error of more than 1° in the sun's apogee. The error of 5½ degrees committed by Ptolemy, is very surprising. The statement of Prof. Whitney that the Hindus borrowed the figures for apsides and nodes from the positions given by Ptolemy or by some earlier Greek writers is, therefore, incorrect. He has never himself compared the positions of the apsides and nodes calculated from European tables for Ptolemy's time, or for Saka 421 or for any other time. He himself says that finding their positions involves a very intricate and laborious calculation\*. But it is not particularly difficult. Looking to Whitney's general ability, it can be said that the calculation of the places was not a difficult task for him. He has certainly, not considered the matter properly, and an inference drawn, without making proper comparison, is bound to be mistaken. The very differences of 3 to 82 degrees between Ptolemy's figures and those of our works in the positions of apsides and nodes, show that the two have absolutely no connection. The position of the sun's apogee alone will prove this. The sun's

apogee according to the writers of our Siddhantas has remained near about 78 degrees from Saka 421 to this date. It is not known since how long it had remained there before the date. Different Siddhantas differ widely from one another in respect of the places of aphelia of other planets but not in the case of the sun. Had the Hindus borrowed the positions of apsides from Ptolemy's work, how could they have changed the position of the sun's apogee from  $65^{\circ}$  to  $78^{\circ}$ ? It will be seen at different places in this work that, while borrowing the positions of planets from other works, the authors of our works do not allow a discrepancy even in seconds. This shows that the apsides mentioned by our works have been independently calculated. Even the apsides and nodes of our own Siddhantas differ considerably amongst themselves. This shows that even the authors of our Siddhantas did not borrow figures from one another, but each of them found them out independently. Whitney remarks that "the Hindus were not capable enough to derive such data as the apsides and nodes for themselves or to modify or improve them when borrowed from other sources, according to the lapse of time"; but on the contrary, this very charge can be made against Ptolemy. The sun's apogee  $65^{\circ}30'$  given by Ptolemy was correct for the times of Hipparchus who lived in 150 B. C. It shows that Ptolemy might have taken the figure without applying a suitable correction for his time. Calculation shows that the aphelia and nodes of other planets also agree with those true for the time when Hipparchus lived. It appears from this that Ptolemy might have adopted even these figures in use in the time of Hipparchus without applying suitable corrections. But no information is at present available to show what positions for the apsides and nodes were assumed in the time of Hipparchus or before him and hence nothing can be said with certainty about this. It is left to the readers to consider, if the Hindus could have borrowed the positions of apsides and nodes either from Ptolemy or from earlier Greeks\* when the figures for apsides and nodes given by Ptolemy were so erroneous and had no similarity with those obtained from Hindu works, and when it is not known at present what positions were accepted in Ptolemy's time. Ptolemy's figures showing the positions of apsides and nodes which were possibly borrowed by him from Hipparchus, and those derived from our old works differ from  $3^{\circ}$  to  $30^{\circ}$  in the case of the apsides and from  $4^{\circ}$  to  $82^{\circ}$  in the case of nodes. If we assume that the Hindus adopted these figures in their works after applying a suitable correction to Hipparchus figures, basing their calculation on the changes in both, which took place within a period of 650 years, which elapsed from the time of Hipparchus (150 B. C.) to Saka 421 (500 A. D.), the difference ought to have been uniform throughout, but it is not so, and had they assumed the difference to be due to their motion in 650 years they would have given a larger figure for the motions of the apsides and nodes, but they mention a figure which is less than  $1^{\circ}$  in 13000 years. This shows that the Hindus did not borrow the apsides and nodes even from the works of the Greeks who lived earlier than Ptolemy. There is another proof that the authors of our Siddhantas found out the positions of apsides and nodes true for their times independently. There are no means to know, if the original Surya-Siddhanta had given revolutions of apsides and nodes in a Kalpa or not. The Patcasiddhantika does not give these. First Aryabhata has not given also, but he has given their positions for his time. This shows that he must have come to know that the motions of apsides and nodes, if they had any, were extremely slow, but he has not given the revolutions of their motions in a yuga, as they could not be detected in a short period. Bhāskara II, while

\*This remark is based on Whitney's statement.



doubtful if the line is the quotation of Pṛthūdaka or of Amaraśa. Weber has quoted another statement of Amaraśa that ŚARĀNANDA was born in Śaka 917, But the work, *Bhāṣavāṭikarāṇa* of Śatānanda has taken Śaka 1021 as the epochal year. There is no other well known Śatānanda. From this, Amaraśa's statement about Śatānanda appears to be quite incorrect; and hence, if it is made by Amaraśa at all, it also deserves little or no consideration. The second point to be considered, is that Amaraśa's statement carries little weight since he lived after Śaka 917, that is 4 or 5 centuries later than Varāhamihira. Considering also the correctness or otherwise of our manuscripts, if the above quoted line be in prose, it leaves room for doubt, if it has come down to us in its exact form. It is, therefore, clear that it is better to accept Śaka 427 which is given in his own work and which leaves no room for any doubt according to planetary positions given in it, as more reliable than to say, after relying on such a quotation, that Varāhamihira died in Śaka 509. It is true that the Śaka year which is adopted by a Kārana work need not be the year in which the work was completed. Thus Keroṇṇa's work has given examples for Śaka 1772, though it was printed in Śaka 1782. In the same way, Varāha's work could have been completed after Śaka 427. Even then, the calculations concerning the work might have started in Śaka 427 or in about a year or two before or after it. Otherwise there seems to be no other reason for adopting Śaka 427 as the epochal year. If he was not born in Śaka 427, there was no possibility of adopting that Śaka. This shows that he was not born after Śaka 427; not only this but it is felt that he must have been at least 15 or 16 years old in that year, and he must have selected that year for solving examples; and that is why the year appears in the work. There is no other probable reason for its mention in it. The mean sun's entry into Aries occurred nearabout the first lunar day of the light half of Caitra (i.e., *amanānta* Vaisākha) in Śaka 427; and he must have adopted the year Śaka 427, because it was convenient to calculate the mean positions of planets for the moment and to describe the method of calculating *śaṅgana* from the 1st lunar day of the light half. It is just possible that the work might have been actually compiled even later. But even then, the mean sun's entry into Aries appears to have occurred near about the first lunar day of the light half in Śaka 419 before Śaka 427 and in Śaka 438 before that year. The year 419 need not be considered at all and the figure 438 has not been adopted. This shows that the work was completed before Śaka 438. The *Pañcasiddhāntikā* mentions *Āryabhaṭa's* name and his work was compiled in Śaka 421; hence, one may be led to raise the objection that there was hardly any possibility of *Āryabhaṭa's* work having become so famous in a period of 6 years; but the objection is not worth much consideration. Varāha's work could possibly have taken 4 or 5 years more after Śaka 427 for completion. It is, therefore, not quite impossible for the well known astronomer, devoted to the same work and residing in the famous city of *Avanti*, to have noticed *Āryabhaṭa's* work or to have known his view as able to do calculations. If, therefore, it be supposed that he was 15 years old in Śaka 427, his year of birth comes to be Śaka 412 and if Śaka 509 be supposed to be the year of his death, his age at death comes to be 97 which is not an impossibility. The birth-year of Varāhamihira, then, from all considerations comes to be about Śaka 412. It is just possible that he adopted Śaka 427 as the starting year, because it was his year of birth. There is however, no doubt that his birth year is not later than Śaka 427.

॥ भवतीत्यप्यवकाशमस्ति तद्वद्विज्ञानमप्यवकाशमस्ति ॥  
॥ क्वात्। वरहीमदरे। गृधः। ममाया। रत्नाणि च वरहीचनं च विभक्तम् ॥

|| : hshhshshshshshsh

It is stated in the verse that the work was commenced in 3068 elapsed from Kālī, that is, in Vikrama Samvat 24. But it also describes the following method of finding ayanārṇśas for a particular year.

**HIS LINEAGE, RESIDENCE, ETC.**

॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥

॥ ३ ॥ शिवलिंगो मुनिमतामयवर्णस्य सम्यग्गोरो वराहमिहोरो रोचिरो अकार ॥ ३ ॥

उपस्थितः।

३०४२ एवमपि विवेचयामासुः ॥ ३०४३ ॥

[illegible]

॥ : ॥॥॥॥॥॥॥॥

(*Meaning* :—The Brahmapa 'Varaha' son of Adityadasa and progenitor in Vedāṅgas, was born with the blessings of the god Sun, on the 8th lunar day of the light half of Caitra, in the year named Jaya, in the Yudhisthira Saka 3042). Varahamihira, the author of *Pañcasiddhāntikā* also was "son of Adityadasa, who got him with the blessings of the god Sun". But the year mentioned in this verse does not agree with calculation by any method whatsoever; hence, the verse is not reliable.

This shows that Adityadāsa was the name of his father, from whom he mastered all knowledge. He received blessings from Sun at Kāpīthaka and was the resident of Ujjayini. Kāpīthaka must be a place near about Avanti, and he might have lived there for some time. That he was the devotee of Sun, is apparent from the prayers chiefly offered to Sun god in the benedictory verses he has given at the beginning of all his works. The following verse from the Pañcasiddhāntikā shows that his tutor in astronomy was a person different from his father :—

॥ १ ॥ : कृष्ण प्रभुः स हस्त्यनुसृतं कृष्णं स उग्रं कृष्णं

.. That he was the resident of Ujjayini can be seen from 4 or 5 of his references made elsewhere.

Some people are found to believe that Bhaskarācārya went to Greece to learn 'astronomy'. But, looking to his works and to those of his earlier writers, this belief appears to be quite baseless. The same remark is also made about Varāhamihira by some. But his works and Bhātṛpala's commentary on them show that works on all the subjects dealt with by Varāhamihira in his works existed in plenty in our country before him and hence he had no reason to go to a foreign country.

He has compiled works on pilgrimage (travel), marriage, mathematics (Karaṇa), Hōra (astrology), and Sāṃhitā (Astronomy). His famous work on the Sāṃhitā branch, known as *Bṛhatsaṃhitā* was compiled by him after all other works as can be seen from his own remark made in the *Bṛhatsaṃhitā*.

॥ ०१ ॥ विरचितं विरचितं विरचितं विरचितं विरचितं ॥ ०१ ॥

"I have treated in my Karaṇa work the questions of direct and retrograde motions, the rising and setting of planets and luminaries; the work on Hora-branch which includes the description of birth in detail, has already been des-cribed along with the subjects on travel and marriage".

The work on Horā-branch, alluded to by him, in the above verse, refers no doubt, to the Bihajjātaka. The following verse from the Bihajjātaka shows that the works on marriage and Karāṇa preceded the Bihajjātaka while that on travel (Yātrā) followed it.



888 i.e. about 400 years after Varaha. His remark "others hold this view" in the commentary on Rāhucāra and at other 2 or 3 places, show that there were other commentaries on the Bṛhatsamhitā before Utpalā's time. The commentaries on the Bṛhajjātaka by Mahidāsa and Mahidhara are in the Deccan College collection (See Nos. 341, 343 of 1882—83 A.D.).

#### DESCRIPTION OF HIS WORKS

A more detailed description of the Bṛhatsamhitā, the Bṛhajjātaka and the Laghujātaka will be given later on. A description of the Pañcasiddhāntikā, this works on mathematical-branch, has been given before in almost full details. The remaining points will be dealt with here.

A verse has already been given above which remarks, "I have described in the Karāṇa work the questions of retrograde and direct motions, setting and rising of planets, etc." Later on he observes,

यद् यदा यदा वा यद्यथादिश्यते त्रिकालैः ॥ तद्विज्ञातं करोमि यदा कृतं

सूयसिद्धांति ॥

वृ. सं. अ. ११.

"I have incorporated from the Sūrya Siddhānta in my Karāṇa work, the knowledge of predicting, like the seers of the three times (past, present and future) when and how war will take place."

And all these questions have been dealt with by him in the Pañcasiddhāntikā. This remark and other proofs also show that the Pañcasiddhāntikā itself was his Karāṇa work (i.e. a work on practical mathematics). Nowhere in the book has he mentioned Pañcasiddhāntikā as its name.

अष्टदिशांशवत्ता तारायुद्धं ययवदद्यात् ॥

ययव तारादिभिर्दत्तं ददाति त्रिसंहरः करोमि ॥ ६५ ॥

वृ. सं. अ. १२

"Free from jealousy Varāhamihira has given this excellent short treatise on the planets comprised in 18 āryas."

In this, he calls the work as a Karāṇa and a Tantra. He has, at one more place in the Pañcasiddhāntikā, called the work a Karāṇa or a 'Tantra'. Utpalā has given the name of Pañcasiddhāntikā to the work. It has already been pointed out that he has translated the five Siddhāntas. He has recommended his own corrections to be applied to the mean positions of planets mentioned by the Sūrya Siddhānta.

शुक्रः शरित् १५ शक्राः शरित् १५ ययव ययवसिद्धांति ॥

दश १० दश शरित्शुक्राः शरित्शुक्र ७३० ययव ॥ १० ॥

ययव २५ शक्राः शरित् २५ ययव १२० ययव ॥

"The following corrections should be applied to mean places of planets :— 15 seconds per year should be added to Mars; 10 to be deducted from Jupiter; 7½ to be added to Saturn; 25 to be subtracted from Venus and 120 to be added to Mercury."

It has already been shown above that none of the Siddhāntas of the Pāṭha-siddhāntikā was compiled by Varāhamihira and these corrections prove the fact beyond doubt. Had the places and motions of planets given in any one of them been calculated by him, there was no need of mentioning the corrections. It has been pointed out before that the elements given in Bhāṣavalkarāṇa tally after these corrections are applied.

Varāhamihira has mentioned the mean places from different Siddhāntas. The explanation of eclipses is also given in different ways from different works. However, the following verses from chapters 1 and 18 show that in mentioning them it was Varāha's intention to show that he has rectified in his work those items which the earlier authors of Tantras were unable to do.

प्राप्य त्वं भूतिं भूतिं त्वं भूतिं ॥

तद्वयं भूतिं भूतिं भूतिं भूतिं ॥ ५ ॥

द्वितीयं भूतिं भूतिं भूतिं भूतिं ॥

तद्वयं भूतिं भूतिं भूतिं भूतिं ॥ ६ ॥

समस्तं भूतिं भूतिं भूतिं भूतिं ॥

उक्तं भूतिं भूतिं भूतिं भूतिं ॥ ७ ॥

अथ १

यद्यन्तं भूतिं भूतिं भूतिं भूतिं ॥ ५ ॥

यद्यन्तं भूतिं भूतिं भूतिं भूतिं ॥

अथ २

The above verses mean :—

(No. 5) "That subject which is the greatest mystery, which perplexes the minds of the writers of astronomical works, viz. the eclipse of the sun, I am going to explain in this work, dismissing all jealousy."

(No. 6) "Moreover these are contained in this work, the (rules for the calculation of the) direction, the duration, the period of total obscuration, the hypothesis, the time of the measures (i.e. beginning, middle and ending of eclipses) of the eclipses or (eventual) non-eclipses of the moon, the conjunctions and obscurity of stars and planets, the means of finding the difference in longitude."

(No. 7) "The prime vertical, the rising of the moon, the construction of astronomical instruments; the shadow of the gnomon; other useful matters; the sine of the terrestrial latitude; the sine of colatitude; the declination and other subjects."

Similarly,

(No. 59) "This Karāṇa work has been accurately compiled by Varāhamihira, since Pradyumna broke down in his efforts (over the calculation) of Mars and Vijayamandi over that of Jupiter and Saturn."

It, therefore, shows that he must have done something more than the original works included in the Pāṭhasiddhāntikā. The corrections to mean planets mentioned above is one of such items. There are no means to know

He at first compiled the Karaṇa work. But later on his Saṃhitā works show that his attention was drawn very much to astrology and various natural phenomena, properties of matter and their utility in everyday life. Brahama-gupta has criticised earlier astronomers, but has nowhere criticised Varāhamihira. Bhaṣkaraçārya has praised him and has taken Varāhamihira's quotations in support of his statements in a number of his works. There have been several authors who wrote on 'astronomy' as a branch of *natural science*, but it can be said that there has been no other astronomer after Varāhamihira who has himself treated several branches of natural science itself. It is a matter of pride to us that such a scholar lived in our country in such an ancient time. But while his works on astrology have been found very useful to this day, his works on Saṃhitā have neither been much studied nor been used to that extent. Had the studies of properties of matter continued on the same line without any break, the Europeans could not have surpassed us in this field. But it is misfortune of our country that the tradition was not continued.

BRAHMACUPTA

These astronomers lived sometime after Varāha and before Brahmagupta, that is, between Śaka 427 and 550. Their works are not now available. The view, that the Romāka and Vasiṣṭha Siddhāntas were either compiled by them or with the help of their works, have already been considered before.

श्रीचण्डेश्वरानामस्तु नमः ॥ श्रीचण्डेश्वरानामस्तु नमः ॥  
 पञ्चमस्तु नमः ॥ पञ्चमस्तु नमः ॥ ५० ॥ ७ ॥  
 श्रीचण्डेश्वरानामस्तु नमः ॥ श्रीचण्डेश्वरानामस्तु नमः ॥  
 पञ्चमस्तु नमः ॥ पञ्चमस्तु नमः ॥ ५० ॥ ७ ॥

\*Brahmagupta has criticised Varāhaṃihira for not stating that Rāhu, who envelops the moon while it enters the earth's shadow, was the main cause of the eclipse; but this is really not a defect; and in reality even Brahmagupta did not mean to blame him.



## Elements

—: Siddhanta are given below:—

In a Kalpa which is a period of 432000000 years					
	Measures like sāvana days, etc.	Revolutions in longitudes	apsides	Revolutions of nodes	
Revolut. of stars	1582236450000				
The Sun	.	4320000000	480		
Sāvana days	. . . 1577916450000				
Moon . . .	.	57753300000			
Moon's apogee	. . .	488105858			
Moon's ascending node	. . .	232311168			
Mars . . .	.	2296828522	292		267
Mercury . . .	.	17936998984	332		521
Jupiter . . .	.	364226455	855		63

In a Kalpa which is a period of 4320000000 years			
Measures like savana days, etc.	Revolutions in longitude	apsides	Revolutions of nodes
Venus	7022389492	653	893
Saturn	146567298	41	584
Solar months	51840000000		
Intercalary months	15933300000		
Lunar months	53433300000		
This	1602999000000		
Suppressed tithis	25082550000		

Length of the year =  $\frac{365}{d} \times \frac{15}{gh} \times \frac{30}{p} \times \frac{22}{wp} \times \frac{30}{pyp}$

All the measures in this table are given for a *Kalpa*. No number can be found which can completely divide the numbers denoting the revolutions of all planets, and hence, according to this Brahma Siddhanta the mean planets cannot all come together at one place, at any moment other than at the beginning of *Kalpa*. All the planets come together by mean motions at the beginning of *Kalpyuga* according to the first Arya Siddhanta or the two Sūrya Siddhantas, but they are not so conjoined according to the Brahma Siddhanta. This Siddhanta does not, like the modern Sūrya-Siddhanta, assume any period spent over creation. According to this, the moment of commencement of the *Kalpa* coincides with that of the planets starting to move.

#### Length of Year

The first thing to be remembered is that the length of the year, viz. 365d 30p 22wp 30pyp, as adopted by this Siddhanta, is less than that adopted by any Indian Siddhanta except the Pūṣa and Romaka of the Patakasiddhanta. It has been clearly pointed out in the discussion of the ancient and modern groups of five Siddhantas that the Pūṣa and Romaka Siddhantas of Patakasiddhanta were not in use in Brahmagupta's time. The first Arya Siddhanta and *original* Sūrya Siddhanta were in use in his time. Of them, Brahma-gupta's length of the year is shorter than that of the original Sūrya Siddhanta by 67½ vipalas and by 52½ vipalas than that of the first Arya Siddhanta. This difference appears to be very small, but because of this (small) variation the moment of the mean sun's entry into Aries in Saka 540, according to Brahma-gupta, occurred 54gh 14p 14s earlier than that according to the first Arya Siddhanta and 54gh 43p 14s earlier than that according to the original Sūrya Siddhanta. What then is the cause of this variation? The cause seems to be only one that he assumed the solar ingress into Aries to have occurred on the day on which the day and night were of equal length, i.e. on the equinoctial day, when the sun rises on the horizon exactly in the east. This moment of the solar ingress is nothing but the entry of the sun in the *stāyana* (tropical) sign of Aries. The moment of the sun's actual entry into the tropical sign of Aries on or about the day when Brahmagupta might have taken actual observation, coincided with the moment of the same phenomenon as calculated from Brahma Siddhanta. The moment of the true sun's entry into Aries in Saka 509, as calculated from Brahmagupta Siddhanta comes to be 56gh—40p after mean sunrise at Ujjayini on Tuesday, the 3rd lunar day of Caitra Suka, the 18th March 587 A.D.; and the time of the entry of the sun into *stāyana* Aries (i.e. sun's longitude being 0° 0') comes to be the same moment on the same day during that year\*. Brahmagupta was born in Saka 520. He might have begun the taking of observations from about Saka 540. Hence, the calculation, according to Brahmagupta, for the year Saka 540, shows that the apparent Aries ingress appears to have occurred at 57gh—22p (after sunrise) on Saturday, the first lunar day of the dark half of Caitra and the tropical

\*The *stāyana* calculations have been made with Karopant's *Phaenomenary Tables*. As these tables are not quite accurate, the phenomenon will perhaps be found to occur a year earlier or later. Similarly, the secular equation has not been applied to the sun's place in the above calculation, it would come to about two minutes, which may cause a variation of a year or two.

longitude of the sun comes to be  $0^{\circ} 30'$ , which shows that the  $\text{śāyana}$  Aries ingresses took place about 30gh before the moment calculated from Brahma Siddhānta. But the sun's declination increases only by 12 minutes in 30 ghats nearabout the - equinoctial time. Hence, in Saka 540, the sun must have been to the north of the equator by 12 minutes at the moment of the sun's entry into Aries according to Brahma Siddhānta, and if the sun had come to the first point of Aries (Mesa Saptakramana) according to Brahmagupta, at sunrise, the sun's centre would have appeared 12 minutes to the north of the east point. But it is not that the equinox always takes place at the time of sunrise. Any one experienced in the taking of observations will easily admit that an error of 12 minutes arc is possible because errors of some minutes can occur in the determination of directions and also the fact that the instruments of observations used to be crude; and these considerations lead me to be convinced that he must have taken the sun's entry into the tropical sign of Aries as the moment of Mesa Saptakramāṇi. He overcomes in the Siddhānta,

अथ त्रयः प्रजातिः सप्तकर्मसिद्धयर्थं सप्तकर्मः ॥

स पक्षः प्रजातिः सप्तकर्मसिद्धयर्थं सप्तकर्मः ॥ ४ ॥

अ. २४.

"If Siddhāntas are different, so must be the moments of the sun's entry into signs; but when the sun is on the equator, it is actually seen rising exactly in the east."

The purport of the verse is that the moments of the sun's crossing as seen in the sky will not appear\* to be occurring at different moments. This refers to the sun at the time of sunrise on the equinoctial day. It is clearly the place of the tropical sun and Brahmagupta has clearly recorded the place by actual observation. Brahmagupta did not know that the equinox has motion and even if it were known before his time, he undoubtedly did not take it into consideration. Hence, he does not differentiate between the  $\text{śāyana}$  place of the sun and that found by calculation from his works (i.e.  $\text{nirayana}$ ). He attempted to see that the place calculated by his work will exactly tally with that of the tropical sun; but this was a correct step only so far as his own time was concerned. The reason for this is that though equinox occurred 54 ghatis before the calculated time, but yet he could not ignore the traditional belief that the mean sun was at the first point of Aries at the commencement of the Kālyuga (i.e. at sunrise, on Friday, according to his view). He, therefore, distributed the error of 54 ghatis over the period of 3730 years (the period between the commencement of Kālyuga and the date of compilation of the Brahma Siddhānta) and he so effected the adjustment that his work should give the moment of equinox to tally with the entry of the sun into the tropical sign of Aries, that is, the moment when the sun actually appeared to rise exactly in the east. This adjustment diminished the length of the year only by a few vipalas. If he had not to encounter the difficulty of distributing the error over the period from the Kālyuga to his own date, and if he had just considered how much earlier than a particular date the equinox had begun to occur in his time, he would have done one of the two things—accepting, for the length of a year, the measure of the tropical solar year, viz. 365d 14gh 32p, or to retain the traditional length of the year and to assume some motion for the equinox. He compiled the work *Khaṇḍakhadyaka* 37-years after the

\*It is because of this kind of disagreement that he remarks "Brahma Siddhānta is the only real Siddhānta, while others are more compilations" and often criticises other Siddhāntas. The Saptakramāṇi according to others, occurs later by one day than according to his work.

Siddhanta and he adopted in it the length of the year given by the original Surya Siddhanta. This shows that he must have inclined to adopt some motion for the equinox after retaining the length of the year once adopted or even after being convinced that he must adopt the actual measure of the tropical year, as the length of the year; he was not bold enough to discard the traditional length of the year and to alter the one already adopted by him while compiling the Siddhanta. Bhaskaracarya has remarked "how is it that proficient astronomers like Brahmagupta have not mentioned the equinox?" It shows that Brahmagupta's original works make no mention of the equinoctial motion.

### Sayana

Whether the almanac should follow the sayana or the nirayana system is at present a matter of controversy. A point favourable to the followers of the sayana system is noticeable in the above discussion, and it is that it was Brahmagupta's original view that the sun's entry into a tropical sign was the actual 'samyakramana' and it was his desire to alter the length of the year, which he did accordingly. Had he carried on observations throughout his life and compared the results, it was not impossible for a scientist like him to hit upon the correct measure of the tropical year. It may be that he might have come to know it and still was not bold enough to discard the traditional one. The reason for his measure of a year which is shorter than that of others, has not been explained by the author because he was a follower of the sayana system. Even the staunchest follower of the nirayana system will have to admit its corrections.

### Correcting the Planetary Elements and Observations

The numbers showing the revolutions of planets etc., as given by the Brahma Siddhanta are somewhat different from those of the other Siddhantas. However, the comparison of mean places of planets in Saka 421 obtained from the Brahma Siddhanta with those of modern European works (page 63) shows that there is not much difference between them. It shows that Brahmagupta adjusted the numbers of planetary revolutions so that the calculated planetary positions for his time would agree with observations. The result of the comparison of apsides and nodes made on page 68 above also shows his independent research in that direction. Hence, the length of the year, the numbers showing revolutions of planets, nodes and apsides, point to the fact that Brahmagupta was an independent research worker who used to take observations for himself; and this is the main important factor in astronomy. His works reveal at several places the spirit of independence and self-respect expected of such a personality. He says in the Chapter on true places,

गुप्तः पृथग्निर्वाचयति त्रैलोक्यं  
निरास्य त्रैलोक्यं त्रैलोक्यं त्रैलोक्यं ॥ ३१ ॥

"The true places obtained from the elements, like epicycles, aphelia and the mean sun and the mean moon, as mentioned by Brahmagupta, give the correct truth; that obtained from other sources is far from accurate." See Golabandhikara—commentary on couplets 17-19.

He maintains here that the tithi calculated from other tantras is far from accurate and that the tithi calculated on the basis of the sun and the moon according to Brahma Siddhanta is correct.

अथ तत्त्वज्ञानात् तत्त्वज्ञानात् तत्त्वज्ञानात् ॥

तत्त्वज्ञानात् तत्त्वज्ञानात् तत्त्वज्ञानात् ॥ ३३ ॥

२. २.

"The true places of Mars and other planets calculated from the ignorant Aryabhata's work giving mean positions of planets, aphelia and epicycles, prove to be wrong, they are found correct when calculated from the mean positions and other elements given by Brahma Siddhanta."

Here he maintains that the positions of Mars and other planets are correct when calculated from the aphelia, epicycles and mean planets according to Brahma Siddhanta but are incorrect according to Aryabhata. There are many such instances showing his pride. This pride has, in some cases, run to such excess, that one cannot help feeling that it is little short of arrogance. He has appended in his Siddhanta an independent chapter, named, 'dūṣaṇa-dhaya' (No. 11) consisting of 63 couplets. Some of the charges levelled against Aryabhata in it show sheer obstinacy on his part.

#### *Subject matter of Brahma Siddhanta*

He has incorporated in the first ten chapters of his Siddhanta, the chapters which are usually found occurring in almost all the Siddhantas and been enumerated in the 'Introduction of this book'. But he has treated many more subjects in the next 14 chapters and they are very important. One of them is the chapter of criticism. One deals with *arithmetic* and another with *algebra*. Yet another describes *instruments*. Most of the remaining chapters are devoted to the theory underlying the subjects dealt with in the first half. The 12th chapter is devoted to arithmetic, mensuration etc. the 56 couplets of which, include almost all the questions dealt with in *Bhāskara's 'Līlavati'*. The 18th chapter mainly treats of algebra, and contains 102 couplets, but nowhere does it actually mention the word algebra. The chapter is entitled '*Kuṭṭaka*'. It contains a number of subjects found in *Bhāskara's 'Bījagaṇita'* (algebra). It contains a chapter headed '*Kuṭṭaka*' and it is given, mainly for being used in the calculation of mean places of planets etc. in astronomy. The Brahma Siddhanta has 24 chapters and contains 1008 couplets.

#### *Commentary*

The Deccan college collection has a copy of the commentary by PITHUDAKA on the first ten chapters. Colbrooke has recorded that he had obtained the complete commentary. Colbrooke translated the portions dealing with arithmetic and algebra from the Brahma Siddhanta into English in 1817.

#### *Interpolation and Yogas*

*Brahmagupta* has mentioned the number of verses at the end of every chapter. It seems to have taken this precaution, because he knew from

experience that changes are often made later in the original. In spite of this recension there appears to be a discrepancy in respect of a few couplets in the work. Three couplets are actually found in the book without any commentary but they are not found at all in the commentary by Prithudaka. One of the three couplets in the chapter on true places is particularly noteworthy in that it deals with Viśkambha and other yogas. It describes the method of calculating yogas, but it is not found in the annotated edition. One is, therefore, inclined to believe that Viśkambha and other 26 yogas which form a part of the present almanac, did not exist in Brahmagupta's time, that is to say, Viśkambha, Vaidhṛti and other yogas did not exist in his time. They are not given even in the Pañcasiddhāntikā. This point will be discussed separately in the study of almanacs.

### *Khaṇḍakhādya*

It is now proposed to review briefly his work 'Khaṇḍakhādya'. The name 'Khaṇḍakhādya' is strange and the object of giving such a name is not known. This has two parts Pūrva (first) and Uttara (second). The first part consists of 9 chapters which contain 194 couplets. The second part consists of 5 chapters comprising of 71 couplets. Brahmagupta observes in part one, at the very outset :

अथर्वश्रुतिर्ब्रह्मगुप्तस्य ॥ १ ॥

प्रथमोऽध्यायः पञ्चमः पञ्चमः ॥

उत्तराध्यायः पञ्चमः पञ्चमः ॥ २ ॥

"(1) I compile the work, Khaṇḍakhādya, which gives results equivalent to those given by the great scholar, Aryabhata. (2) Since it is impossible to carry on every day affairs with Aryabhata's work, this work is being compiled so as to give easily accurate results relating to matters like birth, marriage and the like."

In these verses he states that he is compiling a Karaṇa work, the calculations of planets similar to those obtainable from the Aryabhata's work which is impossible to use in day-to-day life. The Khaṇḍakhādya has adopted the length of the year (365°—15'—31"=30") given by the original Śūrya Siddhānta and not that of the Arya-Siddhānta; and hence, he had to assume the beginning of the yuga at midnight and not at sunrise as assumed by him in his own Siddhānta, or as in the Arya Siddhānta. The epoch in Khaṇḍakhādya is Saka 587, and the apparent first lunar day of the light half of Vaiśākha (according to the 'amanta' system) falls on Sunday in that year. The epochal positions in it are true for the midnight of Saturday, the new moon day of amanta Caitra, i.e. for the midnight preceding Sunday; and the aharāṇa is to be calculated from that moment. The mean Arices Ingress according to the original Śūrya

Siddhanta falls at 12°—9" on the same Saturday. The epochal positions given are as follows:—

Sun	0	0	32	22	Mercury	9	0	44	49
Moon	0	9	9	43	Jupiter	6	4	25	16
Moon's apogee	10	8	28	9	Venus	10	0	19	14
Rāhu	0	18	47	23	Saturn	9	6	41	16
Mars	3	10	13	6					

If the places of planets, true for the midnight of Saturday, the Caitra Amāvāsya of Saka 587, be calculated on the basis of the numbers of revolutions and other elements given before on page 23—from the original *Sūrya Siddhanta*, all of them except the moon's apogee and node, are found exactly to agree with the above positions. They do not agree with those calculated from the *Ārya Siddhanta*. It appears from this that the *Khaṇḍakhādya-Karāṇa* agrees with the original *Sūrya Siddhanta* with respect to all items like the length of the year, the initial moment for computing *shargana* and almost all the epochal positions. The revolutions of the moon's nodes are not met with in the original *Sūrya Siddhanta*. The place of moon's apogee does not agree with that of the original *Sūrya Siddhanta*, but it does not also agree with those of the *Ārya Siddhanta* or the *Brahma Siddhanta*. The moon's node too does not agree with either of the last two works. As the length of the year and the initial moment of the year adopted for *Khaṇḍakhādya* were different from those adopted in the *Brahma Siddhanta*, it is clear that it was no use adopting for *Khaṇḍakhādya* the moon's apogee and node adopted in the *Brahma Siddhanta*. It is true that the *Khaṇḍakhādya* does not agree with the *Ārya-bhāṭia Siddhanta* completely; still, as some of the elements in the *Āryabhāṭia* were equal to those in the original *Sūrya Siddhanta*, the mean positions of planets calculated from *Khaṇḍakhādya* for Saka 587, almost resembled those from the *Ārya Siddhanta*.

*Brahmagupta*, observes in the very beginning in the latter portions of the *Khaṇḍakhādya*, that he would describe the method of finding apparent places of planets because those calculated from *Āryabhāṭa's* work did not agree with observation. On this, *Varāṇa*, the commentator, remarks, "Brahmagupta has declared that he was going to compile a work as good as that of *Āryabhāṭa*, and he did the same in the first half of the work. In the second half he has mentioned an equation from his own *Siddhanta* to ensure results agreeing with observation. Now only those things which have not been mentioned therein, should be accepted from *Āryabhāṭa's* *Karāṇa* work". This remark and other chapters in the second half show that he has made only such changes while compiling the *Khaṇḍakhādya* as would give accurate results comparable by observation. He has borrowed the following important items from *Āryabhāṭa's* work: the length of the year, mean motions of planets, their epochal positions and the moment of the beginning of yuga. The above remark of *Varāṇa* and other things show that *Āryabhāṭa's* work, referred here, is not his *Siddhanta* now available, but his *Karāṇa* work.

It has been mentioned in the account of *Varāṇa* that an epoch wherein the moment of mean *Arjya* ingress nearly coincided with the moment of the new moon was selected as a convenient moment by the *Pañcasiddhāntikā* also. The two resemble each other in other respects also.

It is really strange that instead of compiling a Karaṇa work equal in merit to his own Siddhanta, he proposed to compile a work and for the most part did compile one equal in merit to that of a staunch rival like Aryabhata on whom he had showered a shower of criticism. There are two reasons for this, one of them must be the fact that Aryabhata's work might have been so popular that he was unable to ignore it and the second reason was that in Saka 587 when he compiled the Khaṇḍakhāḍya, the moment of Aries Ingress according to his own Siddhanta occurred 55½—36½ pāls before that of the original Surya Siddhanta and 54½—55½ pāls before that of Aryabhata. And because of this much difference, the two works would show different intercalary months. The difference in intercalary month and the occurrence of the samkrānti a day earlier, are things easily noticeable even by an ignorant person; and these created an unfavourable public opinion with regard to the introduction of the measure of his own Siddhanta. These two reasons, it appears, could not make him bold enough to compile a 'karaṇa' which would be equal in merit to his own Siddhanta, when Brahmagupta could not introduce his own year—measure, because his samkrānti differed by about less than a day, it is worth considering how difficult it would be to bring into use either Keroṇant's almanac, whose samkrānti occurs about 4 days earlier than that of the old works or the sāyana almanac, whose samkrānti takes place about 22 days earlier.

#### *Commentaries on Khaṇḍakhāḍya*

Varuṇa and Bhaṭṭopala have written commentaries on Khaṇḍakhāḍya. Prithudaka too is likely to have written one, but it is nowhere available. One more incomplete commentary has been found which does not mention the name of the commentator; but he appears to be one from Kashmir as can be seen from the Saka year 1564 adopted for solving examples, and from the fact that the corrections adopted for longitudes of places and the ascensional differences refer to Kashmir. The Deccan college collection has got a copy of the work entitled *Pāṇcāṅga Kautika* (No. 537 of 1875-76 A.D.) which gives tables and methods of calculating figures for almanacs very easily. It has adopted Saka 1580 as the epoch and the whole calculation has been made with the help of Khaṇḍakhāḍya. It does not mention that it is compiled in Kashmir; but it was found in Kashmir and it was made use of the popular local era prevalent in Kashmir. It clearly shows that the author belonged to Kashmir. It also shows without doubt that the Karaṇa, Khaṇḍakhāḍya, was in use in Kashmir till Saka 1580; and from the three above mentioned commentaries on Khaṇḍakhāḍya and from the fact that the copies of the Pāṇcāṅga Kautika in the Poona college collections were found in Kashmir, it is felt that it must be still in use in that province. Bhāskaraśāstrya has referred to Khaṇḍakhāḍya. Albituni, (Saka 950) had obtained the Khaṇḍakhāḍya and quoted from it.

#### *Spread of Brahma Siddhanta*

The fact that Brahmagupta compiled Khaṇḍakhāḍya as a work different from his own Siddhanta shows that he was not sure that he would get any follower for the Siddhanta; and it is natural, as can be seen from following well known remark of Kālidāsa.

अप्रतिपत्तिरयं न स्यात्... ॥

"No performance should be regarded as excellent, until it satisfies the deured".



The verse gives Leo as the rising sign, whose duration on that day was the period between 4—9 ghatas after sunrise. This planetary condition is impossible for any day other than this in these two years. The moon's position mentioned in the verse, is not found to be true for any other day being earlier or later by one day. The object of mentioning this here is that these planetary positions agree only if the length of the year given by Brahmagupta in his Brahma Siddhanta be accepted and by that of no other Siddhanta. The sun, according to the Surya Siddhanta, appears to belong to Gemini on Thursday, the 5th lunar day of Aśāḍha (Kṛ̥ṣṇa), and goes in to Cancer at about 5 ghatas after sunrise, on Friday. By no other Siddhantas does it appear to be occupying Cancer on Thursday. The samkrānti, according to Brahma Siddhanta, appears to occur 61<sup>st</sup> 31<sup>st</sup> pal earlier than the samkrānti of the modern Surya Siddhanta in that Saka year. Similarly, even Mars appears to be occupying the sign of Capricorn on Thursday according to the modern Surya Siddhanta and that of Sagittarius according to the Brahma Siddhanta. In short, the planetary positions are seen to agree quite well according to Brahma Siddhanta and even the consideration of the matter from several points of view leaves no doubt about it. It proves beyond doubt that the Brahma Siddhanta was in use in its original form in Saka 819. This old work was compiled in the Deccan when the King Akālavarga of Rāṣṭrakūṭa dynasty was ruling the Deccan. From this it appears that the Brahma Siddhanta was in use in its original form in the Deccan in Saka 819. The corrections in it have been introduced by some one else later on.

### Corrections

Varuṇa's commentary on the Brahma Siddhanta appeared about Saka 962. It does not refer to any corrections. The work Rājamiṅgaṅkaraṇa was compiled in Saka 964 and it mentions the correction. It appears to have been first introduced then. The corrections include that for even the sun. This correction has changed his length of the year from the original Brahma Siddhanta viz. from 365<sup>4</sup>—15<sup>2</sup>—30<sup>1</sup>—22<sup>1</sup> to 365<sup>4</sup>—15<sup>2</sup>—31<sup>1</sup>—17<sup>1</sup>. That is, it is greater than that of the first Aryabhaṭa by about 2 vipalas. The worry of the Brahmapakṣa compiled after this date are found to be in conformity with the corrected Brahma Siddhanta. The Rājamiṅgaṅka compiled in Saka 964 is the first of such Karaṇa works. The second one is the Karaṇa work named 'Karaṇa Kamalāmarāṇḍa' compiled in Saka 980. The next one, compiled after this in Saka 1105 is the Karaṇakūṭubha of Bhāskaraṭācārya. The Mahādevī Śārāṇī, a work on planetary calculations, compiled in Saka 1238 and the two works Khetakaśiddhi and Candārāṅki of the astronomer Dīnākara and compiled in Saka 1500, conform to the corrected Brahma Siddhanta. Of them, the Karaṇakūṭubha is still in use in some places. The author of the Brahmaphakṣa, and these have been taken from the Karaṇakūṭubha. The Brahma Siddhanta might have remained in use in its original form up to Saka 1000 at the most. It may have gone out of everyday use after Bhāskaraṭācārya. Not only that, but because Bhāskaraṭācārya's Siddhanta Siromuṇi could serve the purpose as efficiently as the Brahma Siddhanta, it appears that Brahma Siddhanta itself might have gone out of use gradually. The quotations from the Brahma Siddhanta are rarely found in works compiled after Bhāskara-

"The original verse as given in this book is very incorrect. This verse and the one corrected by me along with its explanation, may be seen on page 435—36 of Prof. Bhāskara's Report on the search for Sanskrit manuscripts for the year 1883—84."

city. The work *Brahma Siddhanta* is at present not found anywhere in *Maharashtra*, and the same may be true of other provinces as well.

#### *Condition of Astronomy*

There is no harm in saying, on the whole, that all the branches of the system which go to make the science of astronomy in our country, appear to have been completely established in the time of *Brahmagupta*. The necessary variations in the positions of planets were made from time to time later on. It can safely be said that no special reform or research was afterwards made in the system except that of the equinoctial motion. It has already been pointed out above that *Brahmagupta* was an independent thinker as far as the revolutions of planets, the aphelia and nodes were concerned. The elements concerning the calculations of the true places of planets appear to be his own. Even in '*triprasādhikāra*' (*Adhikāra* on three problems) he appears to show a greater skill than earlier writers. He has described the instruments of observation and it is my opinion that the '*turyāntara*' (the Quadrant instrument) was his invention. The subject of Algebra is not found in any of the earlier works, which shows that he may probably be its originator. *Sūryadāsa*, the son of *Jyānarāja*, the author of the work, *Siddhānta-Sundara*, wrote commentary in Śaka 1460 on *Bhāskara* as Algebra. He regards *Āryabhaṭa* as the oldest writer on Algebra. The work of *Āryabhaṭa* I may be said to contain no discussion on Algebra; but that of *Āryabhaṭa* II does contain it. But it will be shown later that this work is more modern than that of *Brahmagupta*. Hence the information available at present leads one to conclude that *Brahmagupta* was the first writer on Algebra. He has not recorded in his work any boastful remarks in the chapter on *Bijagāṇita* that it was he who discovered the subject anew. From this it can be conjectured that the subject might have been known even before his time. But books are not available. *Brahmagupta*, was on the whole, a very ingenious research worker. Even a scholarlike *Bhāskara* has praised him thus "May the work of *jiṣṇu* (i.e. the son of *jiṣṇu*, *Brahmagupta*) who is the supreme mathematician, succeed". Similarly, at another place, he remarks, "when after a long lapse of time, a great deal of discrepancy will be caused, men of genius possessing the ability of *Brahmagupta*, will come to birth, and studying the planetary motions evolved by *Brahmagupta*, will compile work on these sciences". It is quite proper that he has been acclaimed as "a great discoverer of (correct) positions and motions of planets and a very intelligent author of scientific works."

#### LALLA (ABOUT ŚAKA 560)

##### *Works*

A work, '*dhividdhidatantra*', on planetary calculation stands to his credit. *Sudhākara Divedi*, procured it, and got it printed in *Vārānasi*, in 1886 A.D. He has written a *Mūhūrtawork*, named '*Ratnakosa*'.

##### *Date*

Lalla has not mentioned his date or place of his residence. In the chapter on mean places, in *Dhividdhidatantra*, he remarks,

तन्मया विद्वत्पुत्रायैः । तस्मै यत्किञ्चित् कृतम् ।  
तन्मया विद्वत्पुत्रायैः । तस्मै यत्किञ्चित् कृतम् ।

13

1

4

**ĐÁP**

"If it be accepted that the earth rotates, then how can the birds flying in the sky, find their own nests?"

॥ ५२ ॥

Lalla observes, in the Chapter on "misconceptions"

"If it be accepted that the earth rotates, then how can the birds flying in the sky, find their own nests?"

In this, Lalla has criticised those who maintain that the earth rotates. But it is only Aryabhata I who states that the earth rotates. It is, therefore, not probable that his own disciple would hold the opposite view or at any rate criticise him. On the whole, Lalla cannot be the disciple of Aryabhata. Bhāskaraśārya's works mention Lalla's name at several places; but nowhere has he mentioned him as Aryabhata's disciple or even merely as a disciple. Rāṣaṇaṭha, the commentator of Śūrya Siddhānta, has at one place mentioned "Aryādhividdhi-dāntara" which simply means 'a tantra work which increases the intellectual power of disciples'. It is not understood on what basis Paramadīvara has called Lalla as Aryabhata's disciple. The above verses compiled by Lalla himself show that he has nowhere called himself as Aryabhata's disciple. On the contrary from the words in those verses it appears that he was not Aryabhata's disciple.

From this, Saka 420 does not seem to be his date. He must have lived many years after Aryabhata.

Lalla has given  $359^{\circ}$  as the longitude of the junction-star of Revati. The time for the junction-star of Revati to cover one degree to the West of the initial point, according to Lalla tantra (that is, from the point occupied by the sun at the moment of the actual Aries Ingress) comes to about Saka 600. But it has been shown above that Brahmagupta knew nothing about Lalla's work ; Lalla's works describe all instruments except the '*tirya'* (*quadrant*) instrument described by Brahmagupta. It shows that Brahmagupta's work was not known to Lalla. This leads one to surmise that both were contemporaries, but residing at distant places.

Sripati has compiled his work 'Ratnamala' with the help of Lalla's 'Ratnakosa'. Sripati's date is Saka 961. Lalla must have lived long before this date.

This shows that he must have lived about the time of Brahmagupta.

From all these considerations, the author thinks that Lalla's date might be a time near about Saka 560.

### His Ability

It is true that Bhaskarācārya has criticised Lalla, the author of "Dhivṛt-āhida", but he states in the 20th verse above, that he has determined these corrections already mentioned, after ensuring agreement with the observed positions himself. This shows that he used to take observations himself and was a researcher; and this fact was very creditable to him. The corrections given to Mercury and other planets show that the need to find them out must have arisen after a period of time had elapsed after Aryabhata. It has already been mentioned that the Karaṇa works 'Karaṇaprakāśa' (Saka 1014) and 'Bhātānulya' (Saka 1339) were compiled after applying Lalla's corrections to the planets calculated according to the Siddhānta of Aryabhata I.

### PADMANABHA

Bhaskarācārya refers in his algebra to this name as a writer on algebra Colebrooke\* has observed that he appears to have lived before Sridhara, as can be seen from Sridhara's work described below. Hence Padmanābha's date, as compared with that of Sridhara, does not appear to be later than Saka 700.

### Sridhara

Mahāvīra's work described below shows that a writer named Sridhara lived before him and that he wrote a work on 'vyākṛtagaṇita' (arithmetic), similar to that of Bhaskarācārya's Līlāvati. Colebrooke had obtained the book, 'Gaṇit-āśāra', by Sridhara. It contained the subjects of arithmetic and mensuration. It shows, that this person Sridhara and the one referred to by Mahāvīra in his work, must be the same person, and Sridhara's date, as determined from that of Mahāvīra does not appear to be later than Saka 775. Sridhara, mentioned by Bhaskarācārya as the author of algebra, seems to be this very person.

### MAHĀVĪRA

He has written 'Sarasamgraha' a work on 'vyākṛtagaṇita' which deals with arithmetic and mensuration. An incomplete copy of the work came to notice in the collection of books belonging to late Dr. Bhanu Daji. The description given in its beginning shows that Mahāvīra was a Jain by religion and that he had the patronage of the Jain King Amoghavarāṣa. This shows that he lived in the reign of Amoghavarāṣa I, the Jain king of the Rāṣṭrakūṭa dynasty, that is, about Saka 775.

His work 'Sarasamgraha' resembles Līlāvati of Bhaskarācārya but is more extensive and consists of at least 2000 "grantha" (or verses in Anuṣṭup metre). The Sarasamgraha contains some times from 'Miśraḥkavyavahāra' (miscellaneous subjects) from the work of Sridharācārya, mentioned above.

### ĀRYABHATA II (ABOUT SAKA 875)

### His Work

There is another Arya Siddhānta in addition to the Siddhānta of Aryabhata I described before. There is a copy of the work, kept in the Deccan College

Collection, but it is entitled as *Laghu-Arya Siddhanta*. But the author himself calls it neither 'bhat' (extensive) nor 'laghu' (short). In the very first verse he observes.

सिद्धान्तमथैव लघुसिद्धान्तमथैव ॥

अथैव लघुसिद्धान्तमथैव लघुसिद्धान्तमथैव ॥ १ ॥

"This beautiful Siddhanta has been compiled in the 'Arya' metre by Aryabhaṭa who has studied various sciences on planetary motions, elementary mathematics, problems in arithmetic, and algebra".

In this, he calls his work a Siddhanta. This author is more modern than the earlier Aryabhaṭa and I have called him as Aryabhaṭa II and his work, Second Arya Siddhanta, because it is convenient to do so.

### His Date

He has not mentioned his date. He has given in his Siddhanta the mean places mentioned by another Siddhanta known as *Paraśara Siddhanta*. He describes both these Siddhantas,

पराशरसिद्धान्तोऽथैव लघुसिद्धान्तमथैव ॥ २ ॥ अथैव २,

meaning "compiled when a small part of Kaliyuga had elapsed". In this verse he intends to show to the world that the two Siddhantas were compiled very soon after the Kaliyuga had started. But I am quite sure that he lived after Brahmagupta, because, even though he maintains that his Siddhanta was compiled very soon after the beginning of Kaliyuga, he includes himself among the authors of "pauruṣa" (human) works. There is no other proof to show that the length of year or other measures adopted by him were in use before Brahmagupta, and all criticisms levelled by the latter against Aryabhaṭa apply to the first Arya Siddhanta and not at all to this. No subject dealt with in this Siddhanta has been referred to by Brahmagupta. Had this Siddhanta existed in his time, Brahmagupta would not have failed to criticise it in some respect or the other. The *Pañcasiddhāntikā* does not appear to have mentioned the equinoctial motion. It is not found in the works of Aryabhaṭa I, Brahmagupta or Lalla. But it is given in this Arya Siddhanta and the authors appear to have attempted to remove the blemishes for which Brahmagupta has criticised Aryabhaṭa I. His work describes the Yuga-system, and the Kalpa begins on Sunday and Brahmagupta has criticised Aryabhaṭa I that his work recommends the planetary calculation, from the beginning of the Yuga when only the 'mean planets' are said to come together and not the 'true planets'. (see 46th couplet, Chap. 2). But according to this Aryabhaṭa's work, the true positions of all planets are given to be together at the beginning of Creation. All these facts have convinced the author that he lived after Brahmagupta i.e. after Śaka 587. This is the farthest limit of his date. As regards the nearest limit, Bhāskara II has quoted him (in his work). In the 65th verse of the chapter on true places, in Siddhanta Siromai, he observes "Aryabhaṭa and others have mentioned the rising of the 'dikṣā' i.e. the third part of a sign or 10°, to ensure accuracy". Aryabhaṭa I has mentioned the duration of ascendants in terms of arcs of 30° and not of 10°; but Aryabhaṭa II has mentioned the durations for the ascension of 'dikṣās' that is arcs of 10°; in couplets 38 to 40 in the 4th chapter, and such a mention of the duration of 'dikṣās' is not at present found in any work except in that of Aryabhaṭa II. This shows that Aryabhaṭa referred to by

Bhaskaracarya in the above line is not the first Aryabhata, but the second. He has described the method of calculating *ayana* but the equinoctial motion as calculated from it is not found always to be constant, but to increase or decrease much (more discussion about this will be made in the study of the motion of equinoxes). But there is no harm in saying that the equinoctial motion is always constant; the variation in it is exceedingly small. The modern Surya Siddhanta gives a constant motion for it; but the date of its compilation is not definitely known. The work, *Rajamangalika* (Saka 964) has adopted a constant motion for the equinox for all times. No definite proof of the measures adopted (by) earlier (writers) is at present available. From this, Aryabhata II appears to have lived before the equinoctial motion was correctly known. The Bhaitopala's commentary (Saka 888) quotes from several works, but not from the second Arya Siddhanta. It shows that even if Aryabhata II lived before Bhaitopala, he must have preceded him only by a few years.

The time when the *ayana* was obtained from the Second Arya Siddhanta, would be equal to the sun's tropical longitude at the true vernal equinox, comes to be about Saka 900. If he had lived before this year, the date must have been only a few years earlier.

From all these considerations, he seems to have lived about the Saka 875. It has already been shown before (page 33) that the date of his Siddhanta and that of Parāśara, as found by Bentley, are incorrect.

#### *Description of his Work*

His work consists of 18 chapters, which contain 625 couplets. The first 13 chapters deal with all the subjects usually discussed in different chapters in *karana* works. The 14th chapter deals with the celestial sphere and problems concerning it. The 15th chapter consisting of 120 couplets is devoted to *Paigāṇī* (i.e. arithmetic and mensuration); and it contains almost all the questions dealt with in Bhaskaracarya's *Līlavatī*. The 16th chapter is devoted to *bhuvana* (Universe) i.e. the description of the three worlds. The 17th Chapter gives a theory of the mean motions of Planets, and the 18th chapter deals with algebra, and particularly the 'kutaka' problems in it. It gives some special information not given by Brahmagupta.

#### *Numerical Code*

He has adopted the usual conventional code to denote numbers in 'Paigāṇī' (i.e. arithmetic and mensuration) only; otherwise he has used, everywhere else, the letters of the alphabet to denote numbers. These letter values are different from those used by Aryabhata I. They are:—

Consonants	Numbers denoted	Consonants	Numbers denoted
Ka, ta, pa, ya	1	ca, ta, sa	6
kh, tha, pha, ra,	2	cha, tha, sa	7
ga, da, ba, la,	3	ja, da, ha	8
gh, dh, bh, va,	4	jha, dha,	9
ha, na, sa	5	ha, na,	0

While denoting numbers by letters, Aryabhata I has not abandoned the general rule that, "digits are written from right to left" but this Aryabhata has differed from it, and has adopted the system of writing the digits from left to right. Example : According to this system the word 'ghaḍapha' denotes 432.

It has been pointed out in the account of Aryabhata I how confusion is caused by adopting his system of code letters. The same remark applies to this Aryabhata also.

Below are given the numbers of revolutions and other elements etc. in one Kalpa as given by his Siddhanta as well as by that of Parāśara.

	Second Siddhanta	Parāśara Siddhanta
Years spent over creation	3024000	0
In one Kalpa	In one Kalpa	In one Kalpa
Revol. of stars	1582237542000	1582237570000
Revol. of Sun	4320000000	4320000000
Savana days	1577917542000	1577917570000
Moon's revolutions	577533334000	577533334515
Moon's apogee : revolutions	488108674	488104634
Moon's node : revolutions	232313354	232313235
Mars	2296831000	2296833037
Mercury	17937054671	17937055474
Jupiter	364221682	364219955
Venus	7022371432	7022372148
Saturn	146569000	146571813
Solar months	51840000000	51840000000
Intercalary months	15933334000	15933334515
Lunar months	534333334000	534333334515
Tithis	1603000020000	1603000035450
Suppressed days	25082478000	25082465450

Planets      Revolutions of apsides in      a Kalpa      Revolutions of nodes in      a Kalpa

Second Arya Siddhanta      Parāsara Siddhanta      Second Arya Siddhanta      Parāsara Siddhanta

Sun	461	480		
Mars	299	327	298	245
Mercury	339	356	524	648
Jupiter	830	982	96	190
Venus	654	526	947	893
Saturn	76	54	620	630

Length of year, according to Arya Siddhanta.—365<sup>a</sup>—15<sup>th</sup>—31<sup>st</sup>—17<sup>th</sup>—6<sup>th</sup>  
Length of year, according to Parāsara Siddhanta.—365—15—31—18—30.

According to Arya Siddhanta it is assumed that some years have been spent over creation. No such assumption has been made in Parāsara Siddhanta. According to both the Siddhantas the planets appear to come together not in the beginning of Kaliyuga, but at the beginning of Creation. The length of the year according to both is nearly equal to that of the recited Brāhma Siddhanta. This Aryabhata has mentioned the number of revolutions of the "saptarṣi" stars (Great Bear), on the assumption that they have some motion. But as a matter of fact the Saptarṣis have, practically, no motion.

### Parāsara Siddhanta

He remarks about Parāsara as follows :—

पराशरः सप्तार्षिं त्रैविंशतिं वदति ॥ १ ॥

पृथक् ११

"The followers of Parāsara Siddhanta do not accept any 'phala' i.e., result for the mutual aspects of planets";

and after passing the remark,

एतत्तु यत्तु प्रमाणं नैव यत्तु ॥ ११ ॥

पृथक् १

meaning "I describe here Parāsara's view since it is the best in Kaliyuga", he has mentioned its elements. From this, the Parāsara Siddhanta appears to be an independent work; but it is not available at present.

## BALABHADRA

The commentary on Brahma Siddhanta by Pithudaka, cites Balabhadra's name several times and has given a number of verses in 'anusup' metre in his name. Those verses quote, in versified form, the elements given in the Brahma-Siddhanta itself. Even Bhatopala's commentary on the Brihat Samhita quotes some verses and Arya couplets in the name of Balabhadra. They relate to the section on mathematics; they have, however, no connection with the Brahma Siddhanta. This shows that he may have compiled an independent work on planetary calculation. The lines which have been given by Pithudaka as quoted from Balabhadra may have been from his commentary on the Brahma Siddhanta. The author thinks that it might have been customary in ancient days to have at least a part of the commentary in verse form, when the text itself was in verse form. That Paramadisaara has quoted in his commentary on Aryabhatiya, some verses from his commentary on Liliavati would serve as an instance in point. In case Balabhadra had written an independent work, it is not now available. His date is clearly earlier than that of Bhatopala, that is Saka 888.

## BHATOPALA

## His Date

He was a great commentator. He has stated the date of the compilation of his commentary on Bhatujataka in these lines.

यथायत्नं यत्नं यत्नं यत्नं यत्नं ॥ यत्नं यत्नं यत्नं यत्नं यत्नं ॥

meaning, 'I wrote this commentary on Thursday, the 5th lunar day of the bright half of Caitra in Saka 888', and that of the commentary on Bhatiasamhita in the verse.

यथायत्नं यत्नं यत्नं यत्नं यत्नं ॥ यत्नं यत्नं यत्नं यत्नं यत्नं ॥

meaning, 'I wrote this commentary on Thursday, the 2nd lunar day of the dark half of Phalgun in Saka 888.'

If Saka 888 be regarded as an 'elapsed' year, the second lunar day of the dark half of either amanta Magha or Phalgun is not found to fall on Thursday. The 2nd lunar day of the bright half of Phalgun was a Thursday. A Thursday is found to fall on the 2nd lunar day of the dark half of (Amanta) Magha in Saka 887, but not on the 2nd lunar day of either the bright or dark half of Phalgun. This shows that the Saka year 888 referred to in the second verse must be the 'current' year, equivalent to Saka 887 elapsed; and the Phalguna may be the month belonging to the 'purnimanta' system; that is, it must be the amanta Magha.

But the 5th lunar day of the bright half of Caitra does not fall on Thursday either in Saka 888 or in 887. In Saka 887, the day happens to be Friday and in Saka 888, it was a Wednesday. It appears that there must be some error in this; and so long as it is not detected, the Saka 888 mentioned in the verse cannot definitely be said to be a 'current' year. In any case, there is no doubt that the year must be one of the two Sakas, 888 or 887.

## Commentaries

Upala has written a commentary on Khadgakhadya, but its Saka is not known. However, in the commentary on the 5th chapter of Bhatiasamhita, one

comes across the remark "khaṇḍakhāḍya śaṇḍīya vacanaḥ", meaning "as I have stated in the commentary on Khaṇḍakhāḍya". It, therefore, shows that he wrote the commentary on Khaṇḍakhāḍya before this. Similarly, a reference made by him in his commentary, on Bṛhasamhitā (Chap. 44) shows that his commentary on Varāha's travel was written before that on Bṛhasamhitā. He has written a commentary on Laghujātaka also. He has, thus, written commentaries on the following works compiled by Varāha—Yātī, Bṛhasamhitā, Laghujātaka, and Bṛhasamhitā, and a commentary on Brahmasphuṭa's Khāṇḍa-Khāḍya. The commentary on 'Yātī' (travel) is not now available. Those on Bṛhasamhitā, Laghujātaka and Bṛhasamhitā are available in this province, and of them, the first two have been printed.

#### Place

The commentary on Khaṇḍakhāḍya, written on the bark of the birch tree which is now in the Deccan College Collection, was originally found in Kashmir. The author does not think this commentary is available in other provinces. That this commentary was well known in Kashmir can be seen from another commentary on Khaṇḍakhāḍya written in Saka 1564 and from the Paṭaṅga Kautuka written in Saka 1567, both written in Kashmir. It shows that Bhāṭopala was a resident of Kashmir; and Varuṇa, the commentator of Khaṇḍakhāḍya, clearly states that he was a resident of Kashmir.

#### Independent Works

He seems to have compiled an independent work on the mathematical branch as can be seen from a couplet given by him at a place with the remark "as I have stated" in the first chapter of the commentary on the Bṛhasamhitā. He might have taken the quotation from his commentary on Khaṇḍakhāḍya. Bhāṭopala has compiled 'prasnajñāna', a work on 'prasnā' (Questions), consisting of 72 śrīya couplets.

#### Love of Research

It appears from the commentary on the Bṛhasamhitā that Ūpala was a keen researcher of ancient works and his reading was vast. He has written at several places that Varāhamihira had taken the help of ancient works on most of the questions on which he had written, and he (Ūpala) has even cited the names of those works at some places. Ūpala has also given quotations from the authors of ancient Samhitā works on those subjects at all or almost all such places. At some places are found quotations from as many as 8 to 10 authors of Samhitā works. It is clear that all these samhitās were available in his time. Similarly, he has given the quotations and names of several 'pauruṣa' (human) writers of works on Samhitā, Jātaka or some of the subsections of the subjects. Ūpala's commentary on the Bṛhasamhitā would be of great help in assessing the state of the knowledge of various subjects relating to the samhitā branch, and its growth in our country, and because of this and other reasons, the commentary is worth publishing. The commentary is very extensive. The whole volume may be found to consist of about 14000 "grantha" verses and (the above two verses show that) this voluminous commentary was compiled by him in about eleven month's time, which is indeed a very remarkable feat. Ūpala has written a commentary on 'satipadāśikā', a work on Jātaka by Pithyāsa, son of Varāhamihira, a copy of which is kept in the Poona College Collection (No. 535 of 1882-83).

The term "Grantha" in such context means verses in Sanskrit or in any other letters each.





A surprising fact has been noticed in his commentary on Khapdashadya. At the very outset it has been remarked, in his commentary on the calculation of aharāṇa ;

*Translation.*—"So is said in the Siddhāntasiroṃaṇi. If you are calculating ahaṅgaṇa corresponding to a particular day of the week, you will have either to add 1 to or subtract 1 from the result. The same will have to be done in the case of particular tithis. Similarly while finding the 'adhimāsā śeṣa' or 'avama śeṣa' the number of intercalary and 'avama' days in a Kālpa undergoes a similar positive or negative change".

# RAJAMRGANKA

## Date \_\_\_\_\_

**Basis**

There are two versions of the book in the Deccan College Collection under Nos. 526 and 527 of 1875-76 A.D. This verse has been taken from the first of them.

Planet	Right Ascension	Declination	Distance from Earth (A.U.)	Apparent Magnitude	Phase	Position Angle
Sun	10 28 45	0	0	39	6	7 52
Moon	10 9 2	53	0	31	6	20 4
Mars	8 2 9	47	0	45	5	10 30
Mercury	8 1 33	15	0	58	2	16 58
Jupiter	3 1 0	30	0			

The positions of apices and nodes at the epoch of the Karaṇa work have also been taken from the Brahma Siddhanta. The correction suggested in it and the method of finding it is given in the following verse :—

मर्यादा ३१०६ मर्यादा मर्यादा मर्यादा ३१०००० मर्यादा ॥

मर्यादा मर्यादा ३१०००० मर्यादा मर्यादा ३१०००० मर्यादा ॥

मर्यादा मर्यादा ३१०००० मर्यादा मर्यादा ३१०००० मर्यादा ॥

मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ॥

मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ३१०००० मर्यादा ॥

मर्यादा मर्यादा

*Translation.*—Add 3179 to the Śaka year. Divide the sum by 12000. Subtract the remainder from the divisor itself (i.e. from 12000). Divide the smaller of the two (viz the remainder or 12000-remainder) by 200, and multiply it by 3, 5, 1, 5, 2, 5, 1, 5, 4, 2 & 2, respectively in the case of the planets in order (viz. the Sun, the Moon, Mars, Mercury, Jupiter, Venus, Saturn, Moon's apogee, and Moon's node) so as to obtain the respective corrections. They are positive for Mercury, Mars and Saturn, and negative for others.

*Author*

—Chapter on mean places. The Colophon contains the following line :

मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा मर्यादा ॥

*Translation* :—"This Karaṇa work, known as 'Migāṅka', has been compiled with the good intention of satisfying the astronomers, by Śrī Bhōja who is revered by rulers of the earth".

This shows that this Karaṇa was compiled by King Bhōja. The above-mentioned correction is not found in any of the earlier works now available. It appears to have been devised at the time of Bhōja himself. It seems probable that he patronised some astronomers, got them to take observations for a number of years, and after comparing the observed places with those calculated from the Brahma Siddhanta, he finally determined the figures for correction so as to agree with other works also. It is not known if King Bhōja possessed the knowledge of astronomy as would be sufficient to compile a Karaṇa work himself. If not, the astronomers under his patronage may have compiled it and named it after him. But even if that be the case, there is no doubt that the astronomers had acquired the ability to compile a new work in the light of observations only on account of the royal patronage.

*Subject Matter*

This work contains only two chapters viz. one chapter on mean places, and other on true places of planets and the two together contain 69 verses. It appears that they may be calculating eclipses directly with the help of the Siddhanta. This work is not in use anywhere at present; and because of the lapse of many years, the shikharas calculated from it would be a very large number and hence very inconvenient for calculating the mean places; because of this and also other Karaṇa works which have been compiled later, this work may naturally have gone out of use. Even then it appears to have been in use for a



## Advantages

The mean planetary places used to be calculated from the aharṅga in well-known earlier Kārṇa works like the Pāṭha Siddhāntika, Khāṇḍakhādya and Rājamiṅḍika. In other words, they describe the method of calculating mean motions and mean places of planets from the number of days obtained by multiplying by 365½ the number of years elapsed after (epoch of) the Kārṇa work. But the aharṅga increases with the increase in the number of years elapsed, and this causes lengthy multiplications and divisions. If tables showing mean motions for successive periods of days are prepared for calculating mean places, the calculation of mean places of planets would take very little time, or if mean places are found from the number of years elapsed after the epochal year, on the basis of the yearly mean motions of planets, even then it would take very little time. But it is surprising that the Pāṭhasiddhāntika, Khāṇḍakhādya and Rājamiṅḍika, and even well known Kārṇa works like the Kārṇa prakāśa, Kārṇakūṭibhāṣa and Grahalaṅghava which were compiled after them, and from which calculations are made even now, give the extremely laborious method of finding mean places of planets from the total aharṅga. The mean place of a planet can be obtained from 'varṣaṅga' or from tables in one tenth of time or even less required for finding the place by that method. The present work, Kārṇa Kamala Mārtaṅga, has not only given methods for finding planets' places from 'varṣaṅga' but has also prepared tables of motions in period of years in order to save the labours of multiplying the 'varṣaṅga' by the figures of annual motions. This is a great advantage. Some astronomers, who following the Grahalaṅghava, are, in these days, found using tables giving motions for days which are useful in finding planets positions from the aharṅga. Similar tables based on the Pāṭha Siddhāntika and other works, might have been compiled by astronomers at different times; but many ignorant astronomers are found who prefer the overlaborious method given in the old works instead of making use of tables, because these are not met with in the works. The author of Kārṇa-Kamala Mārtaṅga deserves praise in this respect. The work gives the calculation of mean places of planets from the mean Aries ingress. It is somewhat surprising that the positions at the epoch and the yearly motions are not given in verse form; but it seems that these may have been given in the tables which accompany the work. The work seen by the author (Deccan College Collection No. 20 of 1870-71) however, contains tables for 'Tithi Suddhi' only. The work, as it stands, is not sufficiently useful for making planetary calculation. It contains the following ten chapters consisting of 279 verses in 'anuprup' metre:—mean places (of planets); three problems; lunar eclipses; solar eclipses; risings and settings; elevations of the moon's cusps; sol-lunar parallels of declinations; conjunctions of planets; true intercalary months; and calculation of the samvatsara (year). This work has assumed Śaka year 444 as the precession year and one minute of arc as the annual rate of precession.

The Aufrecht catalogue mentions another work by Daśabala, entitled *Cintamani Saranika* which contains tables useful for almanac-making. Daśabala claims that the work of almanac-making can be expedited to a great extent through the aid of his work. He also appears to claim that the like of his work was never compiled before.

*Date and Author*

|| ॐ नमो भगवते वासुदेवाय ||

From this it is clear that, the astronomer, Brahmadēva, compiled this work following the (principles of) Āryabhaṭīya. The colophon of the work is as follows

श्रीगुरुभ्यो नमः ॥

॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥

नन्वा नक्ष सन्निधिपञ्चम्यां चैवैवमागः

॥ ११ ॥ श्रीगणेशाय नमः ॥

*Translation* :—"There lived a great Brahmana scholar, named Sri Candras who was a (?) Mathura, reputed all over the world, who was the abode of virtues and whose feet were worshipped by a number of kings. His intelligent son, Brahmadeva, after worshipping the feet of Lord Shiva, compiled this very accurate Karana work in metrical form."

It appears from this that Candra was the name of Brahmadeva's father. Candra may have received the patronage, of some king, or else as the above verse indicates, he must have been at least highly respected by some king. The name 'Maithura,' suggests that he may have been a resident of Maithura.

School.

It is said in the beginning that this work was intended to be in conformity with the science of Aryabhata and it is the first Aryabhata who is thus referred to. Even then, the positions and motions of planets given in it agree with those obtained from the First Arya Siddhanta only after Lalla's corrections are applied to the latter. This does not mention the corrections separately. The planetary positions and motions have been determined after taking into consideration those corrections. The epochal positions mentioned in it are true for the mean sunrise of Friday, the 1st lunar day of the bright half of Caitra of Saka 1014.

They are :—

Planet	Right Ascension	Declination	Distance from Earth (A.U.)	Apparent Magnitude	Phase	Position Angle	Parallax (")	Proper Motion ("/yr)	Radial Velocity (km/s)
Sun	12h 16m 32s	16° 32'	0.00017	-26.7	Full	0°	0.0	0.0	39.3
Moon	11h 27m 20s	27° 20'	0.00257	-12.7	Full	0°	0.0	0.0	1.0
Mars	3h 13m 20s	13° 20'	0.00937	-2.9	Full	0°	0.0	0.0	24.7
Mercury	7h 43m 12s	43° 12'	0.01082	-0.7	Full	0°	0.0	0.0	47.4
Jupiter	6h 25m 27s	25° 27'	0.04973	-2.9	Full	0°	0.0	0.0	13.1
Venus	10h 11m 28s	11° 28'	0.00718	-4.6	Full	0°	0.0	0.0	35.5
Saturn	3h 22m 14s	22° 14'	0.00924	-0.7	Full	0°	0.0	0.0	9.7
Moon's Apogee	1h 51m 49s	51° 49'	0.00406	-1.3	Full	0°	0.0	0.0	10.8
Moon's Node	1h 31m 17s	31° 17'	0.00384	-1.3	Full	0°	0.0	0.0	10.8

These positions are found to agree, even to the seconds, with those obtained from the first Aryabhata's after Lalla's corrections are applied to the latter.



met him in Saka 1806. He knew the complete method of calculation based on Karapaprakṣa but he told the author that they did not always make their calculations from Karapaprakṣa. I actually did the calculations for the 'dāśami' referred to above, from Karapaprakṣa and obtained its duration as 54°—59' after mean sunrise and 56 ghaṭis after true sunrise, for the longitude of Ujjayini. In short, the Karapaprakṣa is still in use to a certain extent. The author had to take a lot of trouble in procuring a copy of the work, and get one.

### *The Three Schools*

It must be mentioned here that the tithi, according to Aryapākṣa, is found to be longer by 2 or 3 ghaṭis, only if Lalla's correction is applied to the calculations made from First Arya Siddhanta otherwise not. Hence, it appears that a different criterion governing the observance of Ekādasi, according to Aryapākṣa, might have been introduced, sometime after Lalla, for such criterion could not have existed before. There is a work on 'Muhūrta' (compiled in Saka 1493) known as Muhūrta Māraṇḍa, which states that the tithi according to Aryapākṣa is longer than that according to Brahmapākṣa, by about four ghaṭis. This work and the Grahaṅgāhva show that, in the 15th Century of Saka era, the differences of the three schools (Arya, Brahma and Saura) had become acute and each had its own circle of followers. Karaṇa Kūṭubhala and Rājamaṅgaṭka are works following the Brahmapākṣa. Khaṇḍakādhya can be said to belong to the Saurapākṣa. No independent work compiled prior to Saka 1014 following the Aryapākṣa, is available. Hence, the three schools appear to have become clearly divergent from Saka 1000 or perhaps even from Lalla's time, and their followers might have begun to take pride in their respective creed.

The positions of planets mentioned in Grahaṅgāhva as belonging to Aryapākṣa have been calculated from the Karapaprakṣa.

### BHĀSVATI KARANA

#### *Date, Author and place*

This is a Karaṇa work. It has adopted Saka 1021 as the epochal year. It has been compiled by an astronomer named Sānanda. Ānruddha, the commentator of Bhāsvati Karaṇa, says that Sānanda was a resident of Puroṣottamapuri that is Jagannāthapuri, and that the epochal positions given by him are true for that place. The convention generally followed is that the epochal positions are given as for Ujjayini, irrespective of the place where the Siddhanta works are compiled. But the author of Bhāsvatikaraṇa appears to have departed from the convention, since Jagannāthapuri happens to be far away from the meridian of Ujjayini and he was right. Sānanda has, in the beginning, observed, "naṭva Muraṭreṣcarṇāvaṇḍam" meaning, "after saluting

Even four hours labour will not be sufficient to calculate figures for Ekādasi with help of Karapaprakṣa. The author has done the calculation in about three quarters of an hour by another method which is easier than that and still gives results in conformity with the Karapaprakṣa.

the feet of Murari (Lord Kṛṣṇa). From this, Mādhava, one of his commentators, says that he was a Vāṇṇava. "Śaṭananda observes in the first Adhikara-

॥ ३ ॥

Translation.—"Now by favour of God Mithura, I compile a brief work equal to the Surya Siddhanta in merit".

### Basis

Mādhava, one of the commentators of his Bhāṣavatīkāraṇa interprets the word "Mithura" as the sun, and interprets the words "like his Siddhanta" as "from the Surya Siddhanta", and he has attempted to explain the positions and motions of planets in it with the help of the modern Surya Siddhanta, but he has failed in this attempt. He is everywhere required to justify his stand by remarking that "the Ācārya has ignored the slight differences." Mādhava has not at all understood the fact that Śaṭananda compiled this Kāraṇa work with the help of the Surya Siddhanta of Varāha's Pāṭha Siddhāntika. The Pāṭha Siddhāntika appears to have gone quite out of vogue in his time (Saka 1442) and this may have been the reason for misunderstanding. The author has seen many other commentaries on Bhāṣavatī but they do not explain the basis of the 'Kṣepaka'.

The epochal positions given by the Bhāṣavatī are those, true for the moment of true Aries Ingress of Thursday, the New Moon day of the 'amānta' Caitra of Saka 1021. The author could not exactly find for what moment on that day they are true, and hence, he could not verify if they agree upto minutes and seconds of longitude. However, the epochal positions are definitely true for the day of the true Aries Ingress and they agree, for the most part with the figures obtained after applying the corrections (given on page 78) to mean places calculated from the Surya Siddhanta, given in the *Pāṭha Siddhāntika* of Varāha. From this it is proved beyond doubt that the planetary positions cited by Bhāṣavatī are those obtained by applying the Varāha's corrections to the places derived from the original Surya Siddhanta. The annual motions of planets are also given in the same way.

### True Aries Ingress

The calculation of mean places, according to this work, is based, not on ahaṅgaṇa but on 'varṣagaṇa' (i.e. the number of years elapsed), and it has already been pointed in the discussion on Kamalāmārtāṇḍa (page 107) that this method is very convenient. All other Kāraṇa works which advocate the calculation of mean places from 'varṣagaṇa' start with the moment of mean Aries Ingress; but this work starts with the moment of the true Aries Ingress. In preparing his planetary tables Kṛtopant has based the calculation of the planet's places on the true Aries Ingress.

### Centennial System

Śaṭananda's work has one more speciality, viz. that he has adopted a cent-

"The ahaṅgaṇa for verifying the epochal position given in Bhāṣavatī as calculated from (the epoch of) Pāṭha Siddhāntika comes to 216962. One can easily see how laborious it would be to do the multiplication and divisions with this figure. If on the other hand the work had given the rates of annual motion, the base figure would have been (1021—427)—594 and the planetary calculation would have been far more easy."

nal system, for starting the epochal positions and the multipliers and divisors required in the calculation of the motions of planets. It doing so he has mentioned the positions and motions of the Sun and the Moon in terms of Nakṣatras and those for Mars and other planets in terms of Rāśis (Signs). The author quotes two examples of this. The rate of annual motion of the moon has been given as  $995\frac{1}{2}$ —These are centesimal parts. This number, divided by 100, would give the required number of Nakṣatras. This would give  $995\frac{1}{2} \times 800$

This system is somewhat similar to the present decimal system. One cannot say if the author of this Karaṇa work adopted the name Sātananda because he loved the Sātanḍa (centesimal) system.

### Contents

The Bhāṣavati consists of the following eight *Adhikāras* (chapters)—(i) 'tithi dhruva' (ii) 'grahadhruva' (iii) true tithi (iv) true places of planets (v) three problems (vi) lunar eclipse (vii) solar eclipse and (viii) graphs. These consist of about 60 verses in all in different metres.

Bhāṣavati has assumed Śaka 450 as the zero precession year, and 1' as the annual rate of precession.

### Commentaries

There is a commentary on Bhāṣavati written in Śaka 1417 by Aniruddha of Vāṭnāsī from which it appears that there were many other commentaries on it written before. Mādhava's commentary was written about Śaka 1442. He was a resident of Kanaṇḍi (Kāṇyakubja). Another commentary was written by Gaṅgadhara in Śaka 1607. There is yet another commentary dated about Śaka 1577. Colebrooke says that Balabhadra's commentary was written in Śaka 1330. From the catalogue\* of Sanskrit books prepared by Aufrecht, the title of this commentary appears to be *Balabodhini*. According to Aufrecht's Catalogue there are following additional commentaries on Bhāṣavati-karaṇa:—Bhāṣavatikaraṇapaddhati; Tāvatprakāśika by Rāmākṣṇa; Bhāṣavaticaraṇamṇyudāharaṇa by Rāmākṣṇa; Udharaṇa by Sātananda; Udharaṇa by Vindavana. Similarly, there are commentaries by Acyutabhaṭṭa, Gopāla, Cakravartipaddasa, Rāmeśvara, Sādananda and a 'prākṛit' commentary by Vanamālī.

Most of these commentators hail from Northern India. It shows that Bhāṣavatikaraṇa was well known on that side. It is not at present known there, nor did I come across a reference to it in any other work.

### KARAṆOTTAMA

#### Date

This Karaṇa work has been mentioned at several places by Māhadeo in his commentary on Śrīpati Rāmamaṇḍa. Māhadeo quotes from this Karaṇa on

\*The German Oriental Society has published at Leipzig in the year 1891, a very big extensive catalogue of Sanskrit books (Catalogus Catalogorum) prepared by a German scholar. Theodor Aufrecht, on the basis of 56 long lists of Sanskrit books, 19 of which contained particulars of books at different places in Europe and 37 of those available in India.

precession. "Saka vasutyambhara candra hīnaḥ", which means, "Saka diminished by 1038". Similarly, he quotes also the following lines from it:—  
 (i) "kala rūpa yātaḥ karaṇaśaradaḥ sa śatayuta" and (ii) "Karaṇottamādaḥ cāpyāyanaṁśa daśasamkhyāḥ", meaning (i) The precession in Kalas (minutes) is 600, equal to the years elapsed before the date of (compilation of) the Karaṇa and (ii) the āyanaṁśas adopted by the Karaṇottama at its beginning are 'ten'. This clearly shows that the work, Karaṇottama, was compiled in Saka 1038. That Saka 438 was taken to be zero precession year, and that the annual rate of precession was 1'. A statement from the Tājakaśara (Saka 1445) viz that the places of planets should be calculated from Suryatulya, Karaṇottama or Rāja Migāṅka has already been given on page 41. Out of those Suryatulya a might have been a work following the Saurapakṣa; Rājāmīgāṅka has already been shown to belong to Brahmapakṣa. Hence, it seems that the third, Karaṇottama, probably belonged to Āryapakṣa; that it was in use in Saka 1445, is obvious from the Saka year of Tājakaśara. I have not read or heard of the work being available in use anywhere at present.

### MAHEŚVARA

He was the father of Bhāskaraācārya, the famous astronomer and author of Siddhanta Śiromaṇi. His date of birth may be about the year Saka 1000 and his works may have been written about the year 1030 to 1040. The account of his ancestry will be found later in the account of Bhāskaraācārya. According to the inscription of Ananta Deva, his great grandson, he compiled "Sekhara" a Karaṇa work, Laghujātakatikā, a work on astrology, and the work entitled Pratiśṭha vidhidipaka (see account of Bhāskaraācārya). Vittaśata is another work written by him. It may be identical with the Muhūrta work named Vittaśata.

### ABHILAŚTARTHA CINTAMANI

#### THE AUTHOR

King Someśvara III of the Uttara Calukya dynasty, who was otherwise known as Bhulokamalla or Sarvajñya Bhupāla, compiled the work "Abhilaṣṭarthā Cintāmaṇi or Manasollāsa. It contains a number of subjects of which astronomy is one. The work has adopted Saka 1051 as the epoch for planetary calculation. The following lines are found written with reference to it:—

एकचरार्थार्थं तद्वत् १०५१ एतत् तत् । शक्य भोग्यत्वं तत् शक्यम् ॥  
 शक्यत्वात् शक्तिं शक्तिं शक्तिं । तदर्थे शक्यत्वात् शक्तिं शक्तिं ॥  
 शक्यत्वात् शक्तिं शक्तिं । शक्तिं शक्तिं शक्तिं शक्तिं ॥

Translation:—

It appears from this that the work has given epochal positions for Friday, the first lunar day of the bright half of Caitra of the above Saka year, and the places of planets have been calculated from the aharṅga. As the author has not actually seen the work, it is not known from what Siddhanta-work the planet's places have been calculated.

\* See Prof. Bhandarkar's *History of the Deccan* (English) Journal of the Royal Asiatic Society, New Service. 1 DGO/69

Bhāskaraçārya's Siddhāntasīromani cites the names of a number of works, among which there are some which have not been described so far.

Mādhava's Siddhānta Cūḍamāṇi has been referred to twice in Siromani (see pages 234 and 269 of Pandit Bapūdeva's book). This Siddhānta is not now available.

He was a very famous astronomer. Not only is his fame resounding throughout our country for the last 700 years, but it has reached even the foreign countries. A brief account of his work will now be given.

He has the Siddhanta Siromani and the Karaṇa Kūṭhala, two astronomical works, to his credit. He writes in the Siromani.

॥ ८५ ॥ : पञ्च । मन्त्रादिभिः । नमो भूते ३६ लक्षण

—: no;id;suajE

This shows that the year of his birth was Saka 1036 and that he compiled Siddhanta Siromani when he was in his 36th year. The epoch adopted for the Karṇakutubhala is Saka 1105. From this, he appears to have compiled it in that year. He has himself written a commentary named Vasanabhāṣya on two chapters of the Siddhanta Siromani, Grahagaṇita and Goladhāyā. At one place (in the chapter on the solar parallels of declination) in it he observes, "I have similarly quoted the 'Sarakhaṇḍakas' in the karṇa work"; and he has, at some places in the commentary adopted 11° as the ayanamśa. This ayanamśa value of 11°, according to his view, was true in Saka 1105. So he seems to have written the commentary about the Saka year 1105. However, a part of the commentary may have been written before this and some portion may possibly have been written along with the original Siddhanta. He compiled the Karṇa work in the 69th year of his age and a portion of the commentary also was written then. This speaks of his energy and intelligence at such a ripe age. Such people are very rare in our country at present. His works and other works also contain so much evidence about his date that there is absolutely no doubt about it.

## ANCESTRY

Bhaskarācārya has recorded a brief history of his ancestors and has mentioned the place of his residence in the following verses :—

आसीत् सत्सुकाचालीश्वरपूरे श्रीवृषविद्वज्जनं नानासंजनधर्मात् विज्जडविहं शीतिस्थानीना

विश्वः ।

श्रीनरसामंतविचारसारचतुर्षो निःशेषविद्यानिधिः सार्धनामवर्षिभूमिहरेवरेकलो

देवसूक्तसमिधः ॥ ६१ ॥

तज्जलचरणात्तृक्पदमृगमालावतमगदः सुधीर्मूर्धोद्वीक्षकरं विदधयामाकर्मणिमदं प्रकृतम् ।

एतत् प्रवक्तव्यं विदधयामाकर्मणिमदं प्रकृतम् ।

कवि श्रीकृतः ॥ ६२ ॥

गीते प्रकृतम् :

Translation :

(61) There was a Brāhmaṇa, Mahēsvara by name, and belonging to Sāṇḍilya Goṭra, who lived in the village of Vijjāḍavida, which was sheltered by the ranges of Sahyadri mountains, and which was inhabited by learned men well versed in the three Vedas. He was the foremost among astrologers and best of virtuous persons, a treasure of all knowledge and skilled in the study of the Śruti and Smṛiti works.

(62) The poet Bhāskara, who was his son and worshiped his feet was very intelligent and he compiled a Siddhānta work which was aimed at being the enlightener of the ignorant and very much liked by the scholars, which was full of true and clear statements, accompanied by reasoning, which was easily intelligible to learned men and antidote to wrong thinking.

It is clear from this that his gotra was Sāṇḍilya ; his father's name was Mahēsvara from whom he got his learning. His place of residence was Bijjāḍavida, near the Sahyadri mountains.

There is a village named Pātan 10 miles S. W. of Calisgaon, in Khandes ; at present it is a deserted place. In that village there is a stone inscription\* in the Bhavānī's temple. Cāṅgādeo, a grandson of Bhāskārācārya was an astro-nomer at the court of king Singhana of the Yādava dynasty. This Singhana (Siṃha) ruled at Devagiri from Saka 1132 to 1159. Cāṅgādeo built a *māth* (monastery) at Pātan for the teaching works of Bhāskārācārya and those of his descendants. King Saideva of Nīkhumḃha dynasty, a feudal king of singhana made an endowment for the maintenance of this monastery in Saka 1129

\*The Late Bhan Daji discovered the inscription and published it in the journal of the R. A. Soc. N. S. Vol. I p. 414 ff. It was again printed well on p. 340 ff. Vol I. of *Epigraphia Indica*, and Pātan, the name of the village occurs in it.

forefathers and successors of Bhaskaracarya as follows :—

॥ ७६ ॥ श्रीगणेशाय नमः ॥

संस्मृतमना रघुः । श्रीमानमहेश्वरवापुस्त्वोऽर्चनं करोति ॥ १६ ॥

॥: ॐ नमो भगवते वासुदेवाय ॥: ॐ नमो भगवते वासुदेवाय ॥:

॥ ०८ ॥ : ५२५॥ १०५॥ १०५॥ १०५॥ १०५॥ १०५॥

॥ १६ ॥ ॐ नमो भगवते वासुदेवाय ॥ १६ ॥ ॐ नमो भगवते वासुदेवाय ॥ १६ ॥

पञ्चांग शुभः तिथिपञ्चांगविषयः ॥

[illegible]

—: translation

Prabhākara (Sun).

(20) His son, a scholar was so great and famous that his feet were worshipped by groups of scholars, he was the fruit borne by the creeper in the form of learning. he was the store of all knowledge, and he attained so much fame and

was so great that there could rarely be found any one on earth to debate even with his disciples.

(21) Lakṣmīdhara was the son of Bhāskara. He was at the helm of all learned men, who interpreted the Vedas and was the leader of logicians and was an expert in the science of 'mīmāṃsā'.

(22) He being known to be well versed in all sciences was invited by king Jaitrapāla to his court, and was made the leader of all scholars.

(23) From him was born a son named Cāgadeo, who was the senior most astrologer at the court of Emperor Singhana. He constructed a monastery with the intention of propagating Bhāskara's works.

(24) All the works compiled by Bhāskara, the chief of which was the Siddhāntasīromani, and also the works compiled by his descendants, are to be regularly studied in my monastery.

Bhāskara's genealogical table, prepared on the basis of the above verses is given in the margin :—

Trivikrama	1	The gotra and the name of Bhāskara's father in this agree with those given by Bhāskara himself.
Bhāskara Bhaṭṭa	1	According to the inscription, the sixth person upwards from Bhāskara in the table, was the tutor to king
Govinda	1	Bhoja Bhāskara, the author of Sīromani, was born in
Prabhākara	1	Saka 1036. Reckoning 20 years as the average for a generation, Bhāskara, the tutor of Bhoja, may be taken
Manoratha	1	to have been born in Saka 936. Hence it was not impossible for him to be the tutor of king Bhoja, the
Maheśvara	1	author of Rajamāṅga, who lived in Saka 964. The inscriptions further say that Lakṣmīdhara, the son of
Bhāskara	1	Bhāskara, the author of Sīromani, was invited by king Jaitrapāla to his court and that his grandson, Cāgadeo,
Lakṣmīdhara	1	was astronomer at the Court of Emperor Singhana. Jaitrapāla of Yādava dynasty ruled* at Devagiri from
Cāga Deo	1	Saka 1113 to 1132 and his son Singhana ruled from Saka 1132 to 1169.

There is a village named Bahal, 10 miles north of Calisgaon, in Kharod, near the river Girana. There is an inscription in this village in the temple of goddess Saraj. According to this inscription, Maheśvara was the son of Manoratha, of Saṅḍīya gotra; his son was Sripati who had a son, named Gaṇapati. His son Anantadeo was the Head Astrologer at the Court of King Sinha (Singhana) of Yādava dynasty. In Saka 1144, he built the above mentioned temple\* of the goddess. It was he who got the inscription carved. This description of ancestry agrees quite well with that given in the Cāgadeo's inscription. The first ancestor named in Cāgadeo's inscription, is the author of the work, 'Damayanti Katha'.

\*See Prof. Bhandarkar's *History of the Deccan*, (English) p. 82.  
 \*\*This inscription is reproduced on p. 112, Vol. III, *Epigraphia Indica*. The inscription states Dvarka to be the name of the goddess.

## THE PLACE OF RESIDENCE

Bhaskarācārya has not stated that he was patronised by any king, nor do we get such information in either of the two inscriptions. According to his statement, Vijalavida, was the place of his residence. The last two letters of this word suggest that Bid might have been the place. But Bid is a place in the Nizam state, 80 miles to the east of Ahmednager. It is not situated near the Sahyadri ranges, and it is learnt from enquiry that there are no descendants of Bhaskarācārya living there at present. The Līlāvati of Bhaskara was translated in Persian, by Akbar's orders in 1587 A.D. (Saka 1509). The translator has stated in it that the birth place of the author was Bidar in the Deccan. Bidar is a place about 100 miles to the east of Sholapur\* in the Nizam State, but it is not near the Sahyadris. It is a place 30 miles to the east of the well known city of Kalyan. The kings of the calukya dynasty were ruling at Kalyan at the time of Bhaskarācārya. Even though such a great kindgom existed so near, nothing is mentioned anywhere about the association of Bhaskarācārya with it. From this, we may conclude that Bidar was not Bhaskarācārya's place of residence.

It is stated in the 22nd verse of the Canga Deo's inscription that "king Jaitrapala called Lakṣmidhara, son of Bhaskarācārya from the town, 'Patan'. The village of Patan is very near to Devagiri (Daulatabad), the capital of the Yadava Kings and it is near the Candwad hills which are off shoots of the Sahyadris; that is, it is "sheltered by the Sahyadri range", in the words of Bhaskarācārya. The village of Bahāi where Anant-Deo, a descendant of Bhaskara built the temple, is only about 20 miles from Patan. This shows that Bhaskarācārya's original place of residence was, beyond doubt, the village Patan itself or some village near it bearing some such name as Vijalavida. It is not known at present.

## Subject matter of Siddhanta Siromani

The *Siddhanta Siromani* is divided into four main parts which are also called Chapters. Each part has a number of chapters in it. The first part is termed as the 'Pāṭigāpita' or Līlāvati, by the author. This can be said to be an independent work on arithmetic and mensuration. It consists of about 278 verses. In between are also given explanations of examples in prose. In the beginning are given in it some tables of various measures; next follow the terms for the places of digits in a number up to 'parārdha' which is the 18th place. Next come the eight fundamental operations, addition, subtraction, multiplication, division, square and square root, and cube and cube root. They are termed 'parikarmāṣṭaka'. Then come subjects like, fundamental operations for fractions and those for zero, 'ṣṭakarma' (unitary method), rule of three, rule of five, progressions etc. Similarly, these are followed by areas and volumes of different figures and solids. Next come subjects like 'kūṭīakagaṇit, pākṣika viparyaya and sarvaṁśika viparyaya", amongst which is given an example of special importance. "A peacock was sitting on a pole, 9 cubits in height. It saw a serpent at a distance of 27 cubits, approaching a hole at the foot of the pole. It jumped to catch the serpent. Both moved at the same speed. How far away from the pole will they meet?" The answer given is '12 cubits away from the pole'. This answer is correct if the peacock is supposed to have

flown along the hypotenuse of the right angled triangle i.e. 15 cubits in a straight line. But it is worth noting that the important mathematical idea that the path of a flying peacock would be a curve much different from the circumference of a circle which is not found in other Sanskrit works, had occurred to Bhāskaraśārya. It is needless to say that such popular beliefs as that one can count the leaves of a tree by studying *Lilāvati*, are baseless; but they indicate people's reverence for the work. The second part of the work is known as '*biyagāṇita*' (Algebra). It contains the following subjects: — the addition etc. of positive and negative numbers, of unknown quantities and of surds. Then come the chapters on subjects like '*kuṭīka*' and '*varga-prakṛiti*', simple equations of one unknown quantity, simultaneous equations of more than one unknown and equations involving squares and higher powers of one or more unknown quantities. This consists of about 213 verses in all, with some prose portions in between.

The parts known as '*golādhyāya*' and '*gaṇitādhyāya*' are devoted to astronomy. The first part treats of all subjects related to planetary calculations which have been mentioned in the list of *Adhikāra* given in the Introduction. The number of verses in it, including those in the commentary, is stated to be 4346. The part known as '*golādhyāya*' deals with the theory of all questions discussed in the '*gaṇitādhyāya*', a description of the three worlds, a chapter on instruments of observation etc. The number of verses mentioned is 2100. In the end is given a very short but important chapter named '*jyotiṣatī*'. In the middle is given a short chapter entitled '*description of seasons*'; it has been compiled by Bhāskaraśārya only to exhibit his poetic gift.

### *His Capabilities*

Bhāskaraśārya has adopted from the *Brahmasiddhanta* the numbers of revolutions and other elements of all planets given in the chapter on mean places and the degrees of epicycles in the chapter on true places. The corrections to be applied to mean positions of planets have been taken in toto from the work '*Rajamāṅga*'. Even the precessional motion has been taken from earlier works. In short, there is nothing new in Bhāskaraśārya's works which is obtainable by observation; but his work is full of knowledge obtainable only after deep study. This sort of knowledge is the origin of the theory of the Science of astronomy. The work *Siddhantasiromaṇi* has reached such a high degree of excellence on account of various simplified methods and the explanation of their underlying theory, covering all subjects from the trifling calculation of planets' places from '*ahargana*' to abstruse questions like that of parallax and the sine theory, that we can really understand the essence of Indian astronomy by reading even this single work; and it appears that it is on account of this Bhāskaraśārya became so very famous. Several works of varying quality might have been thrown into the background because of this work. In view of the fact that even the *Brahma Siddhanta* which was revered by Bhāskaraśārya like a preceptor, was surpassed by Bhāskara *Siddhanta*, one can easily guess how many other authors might have been consigned to oblivion because of Bhāskara's works. The period from *Āryabhaṭa I* to Bhāskaraśārya is regarded as the most brilliant period so far as the development of Indian Astronomy is concerned. It is during this very period that the Khalīphs of Baghdad in their days of prosperity invited astronomers from India, got the Hindu works translated into Arabic and Latin, and the Arabs and Greeks became disciples of Hindus. It was in this very period that the problem of '*Āyana*' motion was fully studied. Several authors of works might have

flourished in this flourishing period of astronomy; but some of them are now known only in name, while some others are not even so lucky. It is no doubt due to the march of time; but it is felt at the same time that Bhāskara-ācārya was responsible for this to a great degree. No other author of equal calibre was born after him. Bhāskara-ācārya's works are well known in every nook and corner of the sub-continent of India. Not only this, but they have been translated also even in foreign languages. But it is the misfortune of our country that such a genius failed to make any of the important discoveries made in Europe in modern times or even lay the foundation of at least one of them. Bhāskara-ācārya did not make any efforts in respect of observation. The author inclined to believe even from his meagre experience that if he had done it, his intelligence which was devoted to the task of merely explaining theories like a commentator would have definitely been diverted to new discoveries.

His works contain nothing new; still, because he has devoted all his intellectual power to theory, his works do contain some new discoveries which are obtainable by study and not by observation. To him the knowledge of the sphere was at his finger's ends. He has suggested a number of new methods in the chapter on three problems and has shown his ingenuity in dealing with several questions in them. Earlier astronomers had not described, in their study of the gnomon, the method of calculating the length of the shadow in any whatever direction but he alone has described it. He has remarked, "Earlier astronomers had been labouring under a delusion in respect of the calculation of the *Mahāpāl* (Soli-lunar parallel of declination); I described the correct method". Earlier astronomers appear to be regarding the arc of the latitude to be lying along the declination circle, that is perpendicular to the equator but he has clearly shown that latitude is perpendicular to the ecliptic. The correction known as 'udayanāra' is one of his discoveries. It is briefly described here:—

"When finding planets' places from the *abharāṇa*, the days are all supposed to be of equal length; but actually they are not so. Even at the equator, the days are somewhat longer or shorter than 60 *ghaṭis* (i.e. 24 hours) and this causes the difference between the moments of mean and true sunrise. The places of planets calculated from the *abharāṇa* are true for mean sun rise. To deduce their places true for the true sunrise, earlier writers have prescribed the corrections known as 'bhujāntar' and 'cara'. Bhāskara-ācārya has prescribed one more correction known as 'udayanāra'. The sun's motion in the ecliptic is not always uniform. The time of true sunrise differs from that of mean sunrise according to the equation of centre, that is, the difference between the true and mean longitude of the sun. The correction due to this is called 'bhujāntar'. The earth rotates round its axis; it rotates in the plane of the equator and not in that of the ecliptic. It is on account of this fact, that the 30° arc of the ecliptic does not always require the same time to come above the horizon as an equal arc of the equator. The correction necessary to cover this irregularity has been called 'Udayanāra' by Bhāskara-ācārya and this correction is evidently necessary to be applied. The corrections of 'bhujāntar' and 'udayanāra' together are included into one term called 'the equation of time' by the European astronomers. Thus Udayanāra was one of the discoveries of Bhāskara-ācārya. Ranganātha, the commentator of the *Sūrya Siddhānta* has attempted to show in his commentary on the 59th chapter that this correction was desired by the author of the *Sūrya Siddhānta* and has remarked that the author had not mentioned it as it was very small. The author of the *Siddhāntatrayavivēka* has attempted to refute

Bhāskara's argument about the need of the adoption of this correction of 'udayantara', but this attempt has proved futile as it shows sheer obstinacy. The Siddhanta-śromani discusses new trivial questions other than that of 'udayantara' and has in the discussion pointed out at two or three places, Brahmagupta's error.

#### Karaṇa Kūṭhala

The Karaṇa work, Karaṇa-Kūṭhala, has adopted Śaka 1105 as the epocha year. The moment of sunrise on Thursday, the new moon day of Phālguna of Śaka 1104, is the epoch for which the positions are given. The mean places have been calculated from aharṇa. Bhāskara's regard his work as comparable to Brahma Siddhanta, but as a matter of fact, it is so, only when the corrections recommended by Rājamiṅgaṅka are applied. It is also called "Grahagamakūṭhala". It was very well known. Some persons use this for calculation even now. It has already been pointed out that the figures claimed by the author of the Grahalaṅghava, as belonging to Brahmapakṣa, have been taken from this work. There is a voluminous work called "Jagac-candrikāsāraṇi" containing tables which are used to calculate planets' places according to this work. The Karaṇa Kūṭhala contains the following ten *Adhikāras* (chapters) (i) mean places (ii) true places (iii) three problems (iv) lunar eclipse (v) solar eclipse (vi) rising and setting (vii) elevation of moon's cusps (viii) conjunction of planets (ix) Mahāpāta (x) pūrvasambhava (possibility of eclipses). These respectively contain 17, 23, 17, 24, 10, 15, 5, 7, 16 and 5 verses, making 139 verses in all.

#### Commentaries

No other astronomical work can boast of having so many commentaries on them as the works of Bhāskara's. Some of them deal with all the four sections of the Siddhanta-śromani. Some others are written on only the first part called Līlāvati, some on only the second part known as 'Bijagaṇita' and still others deal with the two parts 'grahagaṇitādhya' and 'golādhya'.

The commentaries on Līlāvati are mentioned below :—  
Gangādharā, the son of Govardhana and a resident of Jambusara, has written a commentary called 'Gaṇitāmṛtasāgarī'; it probably belongs to Śaka 1342. This was also known as 'Ankāmṛtasāgarī', and the Aufrecht catalogue states that Lakṣmīdhara was another name of Gangādharā. Gaṇeśa Daivajña, the author of Grahalaṅghava, wrote his commentary known as 'Buddhivijāsiṇi', in Śaka 1467. Dhaneśvara Daivajña has written a commentary called 'Līlāvatiḥsaṇa'. Mahīdāsa has written one in Śaka 1509. The commentary known as Līlāvativṛtti has been written by Muniśvara in about the year 1557. The commentary by Mahīdhara, known as Līlāvativivaraṇa, refers to Muniśvara; from this it appears to have been written after Śaka 1557. The Aufrecht Catalogue mentions the following additional commentaries :—

The 'Gaṇitāmṛta Laharī' by Rāmakaṭṭha, son of Nṛsiṃha, (1339 A.D.); the *Paṭigaṇita kaumudī*, a commentary by Nārāyaṇa, son of Nṛsiṃha (1357 A.D.). Manoranjana by Rāmakaṭṭha, son of Sadādeva; The *Līlāvati-bhāṣya* by Rāmācandra; *Nṛsiṅgādṛṣṭi* by Viśvarūpa; *Gaṇitāmṛtākūpika* by Suryadāsa; the *Uddharaṇa* by Candrasekhara Paṇḍya; *Uddharaṇa* by Viśveśvara and commentaries by Dāmodara, Devaśāyā, Parasurama Rāmā-datta, Lakṣminātha, Vṛndāvana, Śridhara-Maithila etc. Of these, the 'Nṛsiṅgādṛṣṭi' commentary appears to belong to Muniśvara, because Viśvarūpa was another name of Muniśvara.

The commentaries on 'Bijagāṇita' :—The commentary known as Bijana-vākura by Kṛṣṇa, the famous astronomer at the court of Emperor Jahāngir was written in about Saka 1524. It is also known as Bijapallava and Kalpa-lāṭāvatāra. It is very extensive. There is a commentary known as Bijaprabodha written by Rāmakṛṣṇa, son of Lakṣmaṇa, who was the son of Nṛsiṃha Deo of Amraoti. This Rāmakṛṣṇa calls himself a disciple of Munīśvara. From this it appears that it belongs to about Saka 1570. The Aufrecht catalogue mentions "Bijavivṛitikalpalatā" by Paramasukha, and 'Udāharaṇa' by Kṛpārama, as additional commentaries.

Gaṇeśa Daivaṇya, author of the *Grahaḍghaṇa*, has written a commentary on "Grahagāṇitadhyaṇya and Golādhyaṇya". Gaṇeśa, the great grandson of Gaṇeśa Daivaṇya, the author of the *Grahaḍghaṇa*, wrote a commentary known as 'Sīromāṇi Prakāśa', about Saka 1500. The commentary known as *Vasanaṅkalpalatā* or *Vasanaṅvārtika* by Nṛsiṃha, a resident of Golagrām, belongs to Saka 1543. The Marici commentary by Munīśvara or Viśvarūpa is very extensive and the best one. It was written in Saka 1557. Siddhāntaśūryodaya, a commentary by Gopinātha, brother of Raghunātha and son of Bhaṭṭarava, was written after Saka 1450.

The following are the commentaries on the complete work of Siddhāntaśīromāṇi :—Sūryaśaṣṭya, son of Jyānārāja, has written a commentary known as *Sūryaprakāśa* on all the four sections. The part of this commentary relating to Līlāvati and Bija was written in Saka 1460. Paramaśiṣvara, the commentator of Aryabhaṭa I, is said to have written a commentary called Siddhāntadīpikā on the works of Bhāskaraśārya. It appears to have been written on all the four sections. The commentary "Mitabhāṣiṇī", by Rāṅganātha, son of Nṛsiṃha, a resident of Golagrām, was written soon after Saka 1580. The Aufrecht Catalogue mentions the following additional commentaries :—The 'Gaṇitavācīnamāṇi by Lakṣmīdāsa, son of Vācaspati (1501 A.D.) The Udāharaṇa, by Viśvanātha; and the commentaries by Rājagṛhipravāśi Cakraśūdrāmāṇi, Jayalakṣmaṇa or Jaya Lakṣmi, Mahēśvara, Mohandāsa, Lakṣmīnātha, Vācaspati (1501 A.D.) and Harihara. Most of them might be confined to Grahagāṇitadhyaṇya and Golādhyaṇya only.

The *Karāṇa Kūṭihala*, has been commented upon by Sūdhata, by Padmanābha, son of Narmada, and by Śaṅkar kavi. The last commentary has adopted Saka 1541 as the year for its examples. There is a commentary dated Saka 1482, which contains an example; the commentator was a resident of Uṇnata Durga. The place has 4-48 as the *palāḍhā* and 60 yojanas west, as *deśāntar* (longitude). The Aufrecht Catalogue mentions the following additional commentaries :—Gaṇitāśar conformed to Brahmasiddhānta and written by Keśavaśārika; 'Gaṇakakūṇṇadakaṇṇudi' by Harṣagāṇita; the Udāharaṇa by Viśvanātha, and the commentary by Ekanātha. There may be many more commentaries on Bhāskaraśārya's works. The Līlāvati was translated into Persian in Saka 1509 and the Bija in Saka 1597. Colebrooke has published the English translation of Līlāvati and Bijagāṇita in 1817 A.D. Pandit Bāpudeva Śaṣtri published an English translation of Golādhyaṇya in the *Bibliotheca Indica* in 1861 A.D. The translation contains a number of notes. All parts of Sīromāṇi and the Karāṇakūṭihala have been printed at several places in our country.

"The author has taken the information about some of the commentaries enumerated above from other books. He has not seen all the commentaries personally."

Mādhava (Saka 1185) the commentator of Ratnamāla, and other writers have mentioned, 'Bhāskaraśāstra', a work on Mūhūrta. It may be a work by Bhāskaraśāstra. A verse of Bhāskara has been quoted in connection with marriages in the commentary on Vivāhapaṭala by Rāma (Saka 1446). A reference to the work Vivāhapaṭala by Bhāskara was also found in the 'Sārāgīya' Vivāhapaṭala and in other one or two works; and a small volume named Bhāskaraśāstra which is in the Deccan College collection, gives no information other than the author's name. It appears however, that Bhāskaraśāstra might have written a work entitled "*Vivāhapaṭala*".

#### *Anantadeva*

He was a descendant of Bhāskaraśāstra. His inscription at Bahāl dated Saka 1144, has already been referred to above (page 117). He has mentioned in it that he wrote commentaries on "*chandaścityuttara*", the 20th Chapter of Brahmagupta's Siddhānta, and on Bījajātaka.

#### ADITYAPRATĀP SIDDHĀNTA

The Mahādevī commentary on Śrīpati's Ratnamāla has quoted some lines from this Siddhānta. The Mahādevī commentary belongs to Saka 1185. This Siddhānta must, therefore, have been written earlier than this. The Aufrecht Catalogue mentions it as written by Bhojarāja. If it be true, it belongs to about Saka 964.

#### VĀVILĀLA KOCANNA

A karaṇa work by Vāvilāla Kocanna, a Telangana astronomer, belongs to Saka 1220; and the epochal positions in it are given for the afternoon of Thursday, the New Moon day of Phalguṇa of Saka 1219. I have calculated the planet's places from the modern Surya Siddhānta, and they agree with the author's places completely. It, therefore, clearly shows, that the work has been compiled with the help of the modern Surya Siddhānta. The work does not contain the correction to be applied to Surya Siddhānta according to Makaranda and other works. Mr. Warren, an European of Madras, compiled a work entitled '*Kāla Samkalita*', in 1825 A.D. It incorporates the major part of this Karaṇa work and gives some information about it. It appears from this that the work is still in use in Telangana, and almanacs are prepared with its help. These almanacs are known as "*Siddhānta Cāndra-Pāṭāṅga*".

#### GRAHASIDDHI

It is a Karaṇa work. It is also known as Mahādevī Sārāṇi. It has adopted Saka 1238 as the epochal year, and hence, it appears to have been compiled about that time.

#### *Its History*

The author, in the very beginning, observes,

एतद्विज्ञानं यत्किञ्चित् कालेन संपूर्णं भवेत् ॥ १ ॥

which shows that the work was first started by some astronomer, Cakresvara, and then the incomplete work was carried to completion by Mahādeva-

Dhanarāja wrote a commentary on it. Mahādeva has recorded his family history in the last 4 verses of the original work; but the commentator has not commented upon them because the verses are very incorrect. The Anand-āśrama has got a copy of the work without a commentary (no. 2086) which contains the same verses in their incorrect form. One comes to know from it that Mahādeva was a Brāhmaṇa, his Gotra was Gautama. Padmanābha was his father's name and Mādhaba\* his grandfather's name. The Author has come across an old work named 'Jātakasāra', written in Sanskrit and Gujarati. It has recommended the calculation of planets places from Mahadevisārāṇi. The copy of the Mahādevīsārāṇi belonging to the Deccan College Collection was procured at Ahmedabad. The commentator also is the resident of a place near Gujerat, and Mahādeva himself has adopted 4 $\frac{1}{2}$  as the 'palabhā' for calculating the ascensional difference (cara). It shows that he may have been the resident of a place near Surat in Gujerat, and it appears that the work might have been in use in Gujerat for a considerable period.

#### Contents

This work contains about 43 verses. They describe the methods of calculating only the mean and true places of planets. The epochal positions are given for the mean Aries Ingress and the work contains tables for calculating mean places of planets from 'varṣagaṇa', which simplifies all calculation. It has given the positions and motions of planets which are comparable to the Brahma Siddhānta, after the corrections mentioned by Rāja Mīgāṇka are applied.

#### The Commentary

The commentator has given his account at the end. A portion of it is given below :—

अन्तराश्विनम् १६६२ पक्षिहो वृष्टेय पक्षे तिथि-  
 वृष्टेय पक्षे गुरु पञ्चम्याय ( ? ) पञ्चम्याय ॥  
 राजाश्विनकृतवर्षिणीपञ्चमी तिथिः ॥  
 श्रीमान् श्रीवर्षिणीपञ्चमीति श्रीपरीक्षिते ॥  
 श्री गणेशाय नमः ॥

Translation :—(There are omissions and inaccuracies in the text).

"In the village of Padmāvati, on the 8th lunar day of the bright half of Jyēṣṭha in Śaka 1692....."

"There is the King Gajasimha, of Rathod family, who is a Jain and rules..." From this, the commentator appears to be a Jain. He has given Dhanarāja as his name. He has, in the commentary, calculated the longitude of Sirohi, (a place, 30 Yojana's West of Ujjain); and from this, he seems to be a resident of that place. The name of the commentary is Mahādevī Dipikā. It is said to contain 1500 verses. The year 1692, mentioned in the above verse, is a Samvat year of the Vikrama era, and hence, the time of the compilation of the commentary comes to be Śaka 1557.

## NĀRMADA

It has already been observed in reviewing the modern *Sūrya Siddhanta* (Page 43) that there must have been a commentary on the *Sūrya Siddhanta* or some work based on it from the pen of Nārmada. The time of that Nārmada must be Śaka 1300. This point has been discussed further while commenting on the Dāmodarīya bhaīatūya. The commentary or work is not at present appreciated.

## PADMANĀBHA

He was the son of Nārmada mentioned above. His probable date was Śaka 1320, and more information about him has been given in the next para. He has written a work entitled 'Yantra-Ratnāvalī'. The author had with him, its second chapter entitled Dhruvabhramayantra, which bears his (Padmanābha) own commentary.

A review of these works will be found in the Chapter on instruments.

## DĀMODARA

Dāmudara has to his credit a work, Bhaīatūya by name. Its epochal year is Śaka 1339. The author observes,

दायादः श्रीपद्मनाभादाय विरतं यत् ॥  
प्रत्यक्षदृष्ट्यायमस्य तुल्यं त्वत् मुद्रे करुणं करोमि ॥ २ ॥

प्रत्यक्षिकारः

Translation:—

Dāmudara, after saluting the Lotus-like feet of his Guru Padmanābha, compiles this karaṇa work, comparable to that of Āryabhaīa, for the pleasure of learned men(2)

श्रीनन्ददासयुक्तं यत्पितुः श्रीपद्मनाभाय सम्यं यत्ततः ॥

यत्तत् प्रथममनुवृत्तं गृहीत् श्रीपद्मनाभाय मुद्रे विभूः ॥ १९ ॥

श्रीपद्मनाभाय कृतं यत्पितुः श्रीपद्मनाभाय

प्रत्यक्षदृष्ट्यायमस्य तुल्यं त्वत् मुद्रे करुणं करोमि ॥ १९ ॥

उपदेष्टारः

Translation:—May the study of the work made with the favour of my father and preceptor Śripadmanābha, son of Śrinārmadadeva, bring me prosperity. (16)

The virtuous Dāmudara, whose lotus face was like the Sun and who is offered continuous prayers by his good disciples, compiled this Karaṇa (work) (19)

—Conclusion

From this, it appears that Padmanābha was his father's name, who was also his preceptor and the name of his grandfather was Nārmadadeva. In the Dhruva-bhramayantra mentioed above, the author observes in the beginning.

*Translation*:—After saluting the feet of my father and preceptor, who was born because of the favour of Śrināmadadeva, I describe the best of the instruments, the Dhruvabhramayantra, which is useful in giving the time at night (1)

and in the end, the following remark is made:—

इति श्री गणेशाय नमः श्रीधरपुत्राय नमः

काश्यायै नमः श्रीधरपुत्राय नमः ॥

*Translation*:—So ends the second chapter on Dhruvabhramanya, in his self-written work Yantra Ratnavali, which is compiled by Śripadmanābha, son of Śrināmadadeva.

It appears from this, that Nāmadadeva was the name of Padmanābha's father and this leads one to believe, beyond all doubt, that this Padmanābha was Dāmodara's father. Dāmodara's work was written in Śaka 1339. Hence, assuming 20 years for one generation, the date of Padmanābha's work comes to be about Śaka 1320. The work, 'Jātakabhāṣa', (see section on 'Jātakā' later on) written in about Śaka 1460, refers to the Dhruvabhramayantra, which lends support to the above argument. Although it does not prove beyond doubt that the Nāmadadeva whose verse has been quoted by Rāṅganātha (page 43) was the father of Padmanābha, referred to in the above verse, still there is a similarity of names. Padmanābha says that Nāmadadeva, his father, was a scholar and was also his preceptor, and it appears quite probable that he could have been the author of some work. The Nāmadadeva, mentioned by Rāṅganātha, must have lived before him (Śaka 1525) and this does not give rise to any contradiction; and the most important fact is that Dāmodara has adopted in his work, Bhaṭṭa, 54 seconds as the rate of annual equinoctial motion. This is the same as in the Śūrya Siddhānta. None of the 'pauruṣeya' (human) authors of works described so far, have adopted this notion except Dāmodara. From this, it seems beyond doubt, that Nāmadadeva who was his grandfather, must also be the author of the commentary on Śūrya Siddhānta. The date of his commentary may be Śaka 1300.

The work 'Bhaṭṭa' has adopted epochal positions for the mean Aries Ingress of Śaka 1339. They agree with those obtained after applying the Lalla's corrections to First Aryasiddhānta. The sides and nodes are given according to the First Arya Siddhānta. He has adopted 54 seconds as the annual equinoctial motion and Śaka 342 as the zero-precession year. More information about this will be given later on. This work contains the following chapters:—

- (i) mean places.
- (ii) true places.
- (iii) calculation of places of five planets.
- (iv) three problems.
- (v) lunar eclipse.
- (vi) risings and settings and
- (vii) conjunctions of planets.

The author has remarked in the end that the number of metres. It contains, in all, 222 verses in various verses would be 400, if composed in 'anuṣṭup' metre.

He has dealt with the chapter on 'three problems' very extensively. It consists of 87 verses, which contain some problems also and the figure 5 for the 'palabhā' has occurred a number of times in those problems. The first Arya Siddhanta does not mention longitudes of stars. The work 'Karapa-prakāśa' which also follows the Aryapākṣa, does not give longitudes of stars. But those given by Dāmodara are some what different from what one finds in all other works. This speaks of his independent discovery in this respect. A more detailed discussion of this will be found further in the chapter on conjunctions of planets.

## MAKARANDA

Makaranda is a work containing tables which facilitate the calculation of the almanac. It has been compiled by the astronomer Makaranda himself. In the beginning he observes,

शुद्धविज्ञानेन सप्तविश्वोत्कर्षात् गुरुसंज्ञात् ॥

विशुद्धिद्वयं विज्ञेयं फलमिदं कर्षणं ॥ १ ॥

*Translation*:—Makaranda, who is delight incarnate, has, by his precursor's favour, compiled this work containing tables for calculating Tithi etc., on the basis of the Surya Siddhanta for the use of the world.

It shows that this work was compiled on the basis of the Surya Siddhanta and that the author was a resident of Vārāṇasi. The ending moments of tithis etc., given in ghaṭis and palaś, when calculated according to this work, are found true chiefly for Vārāṇasi. The Surya Siddhanta referred to in this, proves to be the modern Surya-Siddhanta from the theory. It is stated in the version printed at Vārāṇasi that the work had adopted Śaka 1400 as the epochal year. There is no other internal evidence in support of this assertion, not does the author find any external evidence. There is, however, no reason to doubt its authenticity. Diwakar wrote a commentary on this work named Makarandavivaraṇa about Śaka 1540. The ending moments of tithis etc., and places of all planets are obtained very easily with the help of this work. The author does not describe the system for want of space. In many parts of Northern India, like Gwalior and Vārāṇasi, almanacs are compiled with the help of this work even at present, and these are used by the local population. This work is printed in Vārāṇasi. The theory underlying these tables has been explained by Gokulnāth Daivaajya in Śaka 1688, and it has also been printed.

The author of Makaranda has recommended a correction for the Surya Siddhanta, which has been mentioned already.

## KEŚAVA

Gaṇeśa Daivaajya, the author of Grāhalāghava, has written a commentary on 'Vivāhāvivandana' which is a work by Keśava. The work, 'Karapa-kāṇṭhirava', was, according to Gaṇeśa also compiled by the same Keśava. This must have been a Karapa work but it could not be procured anywhere. This Keśava was an Audicya Brāhmaṇa of Bharadvāja Gotra. The names of his forefathers, beginning from his father in ascending order, were Rājaga, Sṛyaditya and Janārdana. This Keśava must have lived earlier than the Keśava, the father, of Gaṇeśa, the author of Grāhalāghava. Nirṇayamṛta, a commentary on Pītāmbara's Vivāhapatāla, written in Śaka 1446, refers to the





annual rates of motions. This difference will become very great as time will elapse, since the Brahma and other Siddhāntas show a great discrepancy in the numbers of revolutions and the number of seven days etc. Much greater difference will occur after the lapse of a long time. . . . Hence, the future calculators should calculate planetary places, by adopting the figures of revolutions increased or decreased in conformity with the actual observed phenomena of the conjunction, rising and setting of stars and planets in their own time. Otherwise, short karāṇa works should be compiled by adjusting the epochal positions true for the moment in question. The writer has accordingly found out the mean place of the moon, instead of its maximum equation of centre, by reversed steps, from the observation of the lunar eclipse at the ending moment of the full moon, since, the equation of centre is neither positive nor negative. The moon's apogee was finally fixed by reversing the steps of calculation, after observing the eclipse at the moment of the full moon in the celestial globe of observation, since the maximum correction would neither be plus nor minus. The moon's place was found to be 5 minutes less as compared with that calculated from the Śūrya Siddhānta. The apogee agreed with that of the Brahmāpakṣa. The sun's place showed a small discrepancy in the case of all 'pakṣas'; hence, the writer accepted that belonging to Saurāpakṣa. Places of other planets were fixed after actually observing their positions at the time of their conjunctions with stars and planets. Here the writer has taken the Mars and Jupiter as derived from the Brahma Siddhānta and Mercury's place from Brahmāpakṣa. Venus was taken as occupying the mean position between the Ārya and Brahmāpakṣa. The Saturn was seen to exceed the position given by the three pakṣas by five degrees. Thus the writer has calculated the places of planets by a short method after observing their actual places at the present time.

The writer has not found such a detailed account of results of observations personally taken by any other astronomer and recorded in his own work. As a matter of fact he inclined to think that there never lived another astronomer like Keśava, except the author of the original Śūrya Siddhānta, Āryabhaṭa I, Brahmagupta and the astronomers living in the time of king Bhōja. If he had recorded the day on which the observations were taken and what were the planetary positions found from observation, the record would have been very useful. But it is a matter of regret that tradition never induced the astronomers in our country to record such an account in their own works.

The writer found from calculation that he has adopted in his work, *Graha-kāṇṭhikā*, such epochal positions and annual motions as agreed with his observations.

Keśava has himself written a commentary on the *Graha Kāṇṭhikā* and the *Jātaka-paddhantī*.

## GAṆEŚA DAIVAJĪVYA

He was a very famous astronomer. The astronomical works of no other astronomer are in use all over India at present as those of Gaṇeśa Daivajīvya. His father's name was Keśava, mother's name Lakṣmi, Kausika his gotra and Nandgaon, on the western sea-coast, his place of residence. These facts have already been stated above.

"Visvanātha, in his commentary "Visvanāth" on Graha Laghava, observes, "the works which Ganeśa Daivajña, my preceptor compiled, have been enumerated by his nephew, the astronomer Nṣimha, in two verses in his commentary on Grahalaghaḥva. They are :—

#### HIS WORKS

ऊवादे गणेशव नृपुणैर्व्याख्यादिवाग्मि ॥  
 अविदितानि मे वाग्मि जीवावलीकृति ॥  
 श्रीवृंदावलीकृति च विवर्ति मन्दोत्तरस्य च ।  
 सर्वश्राव्यादिवाग्मि सुविवर्ति सर्वोपवाक्यस्य च ॥ १ ॥  
 सुधीरजं तर्जनीयकं च सुकुलान्दशीनर्पं होतृकया  
 नृपुणैर्व्याख्यादिवाग्मिः....."

*Translation :—*Ganeśa Daivajña appears to have compiled the following works :—The Grahalaghaḥva, the Laghutithi Cintāmaṇi, the Brāhminī-cintāmaṇi, the Siddhāntasiroṃāṇīkā, the Līlāvāṇīkā, the Vivāhaṇḍa-vāṇīkā, the Muḥurtatāvaṇīkā, the Śrāddhānirṇaya, the Candorāvāṇīkā, the Tarjanīyantra, the Kīṣkāsāstānirṇaya, the Hōhikānirṇaya, the Laghu-pāyapāta (i.e. a table for calculating Mahāpāta), etc.

Even Ganeśa has himself mentioned the names of some of his works in his work, *Vivāhaṇḍavāṇīkā*. They are,

ऊवादे गणेशव नृपुणैर्व्याख्यादिवाग्मि ॥  
 अविदितानि मे वाग्मि जीवावलीकृति ॥  
 श्रीवृंदावलीकृति च विवर्ति मन्दोत्तरस्य च ।  
 सर्वश्राव्यादिवाग्मि सुविवर्ति सर्वोपवाक्यस्य च ॥ १ ॥

*Translation :—*(Not necessary)

This list mentions the additional work, *Parvanirṇaya*. It is not that these works have been mentioned in their chronological order. Still, the *Grahalaghaḥva* appears to have been compiled first. In this work, Saka 1442 has been adopted as the epochal year for planetary calculation. At this time he must have been at least 20/22 years of age. In other words his date of birth may have been about Saka 1420. The work *Laghucintāmaṇi* was written in Saka 1447 and the *Līlāvāṇīkā* in Saka 1467. The *Pāśāraṇi* shows that it was compiled some time after Saka 1460. The author has seen a printed Edition of *Vṇḍa-vāṇīkā* and it has mentioned its date of compilation in a curious way. It is given thus :—

#### The Dates

इत्यनेन १२ तदुत्तरायणं तद्युतीर्य ६ युता युतिमेष्व ॥  
 साधु सागर ४ युतिद्वयैकं तद्विज्ञेय २३ तत्र एव पराकः ॥ १ ॥  
 पराः सप्तमी २ युति वासरः स्यात् तदीयरात्रि ३ परमर्कस्वर्गः स्यात् ॥  
 यथाविशेषं \* इत्यमी २१ इव तत्र नदी ६ त्रिकं मरुतकवसरः स्युः ॥  
 वृद्धनिरुपपन्नस्यैवार्थं युतिमेष्व..... ॥

\* (Sampatara Ayana Yuga Nakshatra Pakva Week day Tithi Month +1st +19th +22nd +1st +3rd +1st +11th) × 21 + 9 = 1600.



— calculated from ancient works :—

॥ श्रीगणेशाय नमः ॥

*Translation*:—(not necessary, since the sense is given in the following para).

The places calculated for sunrise on Monday, the New Moon day of Phalguna of Saka 1441, according to the instructions given above agree completely. That is, calculated from the modern Surya Siddhānta, the places of the Sun, and the Moon's apogee and that of the moon diminished by 9 minutes would agree with the positions given above. Calculated from the Karāṇaprakāśa of the Aryapākṣa, the places of Jupiter, Mars, the Moon's node and that of Saturn increased by 5', would agree with the positions mentioned above. The anomaly of Mercury agrees with that calculated from the Karāṇakutubhala of Brahmapākṣa; and the anomalies of Venus, as calculated from Karāṇaprakāśa and Karāṇakutubhala agree with the above position when added up and halved. Gaṇeśa has, however, left out seconds of arc in all the position and increased or decreased the minutes in some cases; hence, in certain cases, there is some discrepancy as far as minutes of arc are concerned. While calculating the places mentioned above, the ahaṛgaṇa for Karāṇaprakāśa comes to 156334 and that for Karāṇakutubhala to 123113\*. It is obvious how very laborious it would be to make calculations with these figures of ahaṛgaṇa. Gaṇeśa has advocated the method of calculating planets' places from the ahaṛgaṇa itself; but he has employed a device by which the ahaṛgaṇa figure is not allowed to increase too much. He has assumed a cycle of the ahaṛgaṇa of 4016 days, since this happens to be the approximate number of days in the period of 11 years; and the planet's mean motion\*\* gives the mean place. The ahaṛgaṇa never exceeds the number 4016 because of this device.

## HIS SPECIALTY

Another speciality of the *Grahāḅhava* is that it has done away with the use of sines and arcs. In spite of this there is absolutely no harm in saying that this work gives results by no means less accurate than those obtained from any of the earlier *Karāṇa* works. Modern English works give tables of sines not only for each degree, but even for each minute of arc; and some works are so compiled that they give the sines of even seconds of arc. Our works give sines of angles of  $3\frac{1}{2}$  degrees and their multiples. Thus, the number of tabular sines is 24; but the *karāṇa* works generally give only 9 (at an interval of  $10^\circ$ ) or even less. Even though the *Grahāḅhava* has not used the sines, the method of finding the sun's true places, as adopted by *Grahāḅhava*,

\* No commentator has pointed out just as the author has done, the particular works from which the different planetary places have been derived by Chinese Jatakyas.

\*\* The period of 11 years gives a variable number of days; and the author has so adopted the device that the error corresponding to this variation would not escape. The exponent of the planet's motion in the cycle is given; if this exponent subtracted from the epochal position and the motion for the aharṇas added to the remainder, the mean position of the planet for the given moment.



their elation to the Sun.

[illegible]

It appears from this that Mercury's place is very erroneous. The places of Venus, Saturn and Moon's apogee show a discrepancy of  $1''$  to  $2''$ . Others show a difference within  $1''$ . The Moon's place is remarkably correct. The place of the Moon's node is not very erroneous. Gaṇeśa's father, Keśava, has already mentioned in the account of his work, about his claims that he ascertained the place of the Moon and Rāhu from the Solar eclipse. It appears that there is such a serious discrepancy in Mercury's place, because, Mercury is not easily observable as it is visible only for a few days in the year. Another fact that must be remembered is that the above errors occur in the mean places of planets. But only the true places of planets are found by actual observation. While considering Bentley's method, it has already been shown on page 30, that the discrepancy in the actual places of planets at the time of the *Grāha-laghava* might have been much less. It has been shown later on in almanacs what is the extent of error seen at present while calculating figures from the *Grāha-laghava*.

Ganēśa observes that the places of planets calculated from certain works tally with their observed places on application of certain corrections; accordingly he has suggested a correction of 5° for Saturn's place, which is very excessive. Similarly he has proposed a correction of some minutes of arc in the case of other planets also. It is quite obvious, therefore, put forwarded the names of ancient works only by way of nominal support while recording the actual positions of planets in his own time.

Keśava, Gaṇeśa's father had almost prepared the ground for applying corrections to old works by taking observations, as he had noticed discrepancies in the planets' places obtained from the earlier works, and he compiled the Graha Kautuka accordingly; Gaṇeśa observes in Laghu Cintāmaṇi that he finally corrected the planets after observing the loopholes still left in that work. A comparison of Graha Kautuka and Grahaśāhava would confirm this statement. In the Chapter on the risings and settings, in Grahaśāhava, he remarks:—

Remarks:—

॥ गुरुदेव गुरुदेव गुरुदेव गुरुदेव ॥

11. The independent member of the

Translation:—(not necessary)

In this he says that it was his experience that the moments of risings and settings of Venus are found to be true when the kalāmas mentioned by earlier astronomers are diminished by two. All these things go to prove that he was himself an observer. One of the legends that has become quite current about him, says that it was not necessary for him to look to the ground, while walking, because his feet had got eyes. This is of course, an impossibility. Still it goes to show that his attention was always directed to the sky while walking. Another legend says that he was always found to be gazing at the sky while sitting on huge slabs of stone on the seashore. This was quite possible. Many such slabs are found on the sea coast in Kanakan and it is very convenient to take observations while sitting in such quiet places.

### Calibre

Gaṇeśa was perhaps able to produce a work like the *Grahalāghava* which proved more accurate in the light of observation than *Graha Kauṭuka*, because his own experience was coupled with that of his father, and although the methods described in *Graha Kauṭuka* are, in some cases, more convenient than those of *Grahalāghava*, still, in certain other matters, the *Grahalāghava* is found to be more convenient. Hence, *Graha Kauṭuka* may have gone out of use giving place to *Grahalāghava*. Considering all things I am inclined to think that his father was more competent than Gaṇeśa himself. However, looking only to the utility of the works the *Grahalāghava* is certainly superior because the experience of both father and son have been combined in that work.

The *Grahalāghava* contains chapters on the following 14 subjects:—  
 (1) Mean places (2) True places (3) Places of five planets (4) Three problems (5) Lunar Eclipse (6) Solar Eclipse (7) "Masagagagrāhaṇa" (8) Approximate places of planets (9) Risings and settings (10) Shadow (11) Shadow of stars (12) Elevation of Moon's Cusps (13) Conjunctions of planets (14) *Mahāpāta*. They contain respectively 16, 10, 17, 26, 13, 13, 19, 8, 25, 6, 12, 4, 4 and 14 verses in different metres and 187 verses in all. At present only these 14 chapters are widely known. But the commentaries of Mallāri and Viśwanātha contain a 15th Chapter of 15 verses entitled "Pāñcāṅgagrāhaṇa". Since the 14 chapters already include 4 chapters devoted to eclipses, this must have been considered superfluous and allowed to be lost. Gaṇeśa appears to have purposely sacrificed accuracy in certain cases because of his tendency to simplify calculations and hence, he has added two more chapters on eclipses (7th and 8th) even when 2 chapters out of 14 had been devoted to the eclipses of the sun and the moon. The addition was altogether redundant. *Grahalāghava* appears to also have undergone certain changes in its different versions. In the copy of the *Grahalāghava* written in Śaka 1605, which the author got at Bārī the 15th Chapter had been omitted while the chapter on "Pāñcārātra" contained 3 more verses which discuss some points about planets' risings and settings. These verses are not found in Viśwanātha's commentary. Some verses show variations in readings. Again the Viśwanāthi commentary contains some verses which are not found in the copy of the *Grahalāghava* printed by Kṛṣṇāśāstri Godbole. A verse describing the method of calculating the moon's latitude accurately is given in the Viśwanāthi commentary and also in Kṛṣṇa Śāstri's edition, but it was not found in the copy obtained by author at Bārī. Different copies of the work give the sequence of certain verses in different ways. It is found at present in the chapter on "nakṣatrachāyā" a

verse, attributed by Visvanātha to Nrsimha, nephew of Gaṇeśa, but it is not to be found in the Bāṣī-copy. Anyway, even though there are some variations here and there, they have not given rise to any perversion so far as the author's original methods are concerned.

#### Other works.

Among other works of Gaṇeśa that are useful for the calculation of the almanac, Brhatcintāmaṇi and Laghucintāmaṇi are particularly noteworthy. They are helpful in quickly calculating figures for tithi, nakṣatra, and yoga. If tithi and other items of the almanac (pañcāṅga) were to be calculated by actually finding the true places of the sun and moon from the *Grahaṅghaṇa*, they would require unremitting labour for six months. If the tables prepared for calculating the mean and true positions of the sun and the moon are utilized, even then one would take according to the author's estimate, about 24 days, of ceaseless labour. But the work *Laghucintāmaṇi* expedites the calculations to such an extent that the tithis, nakṣatras and yogas could be calculated only in three days. The work can be finished still more quickly if the *Brhatcintāmaṇi* is used. And in spite of this economy of labour, it is found by comparison that the difference in ghaṭipalas as obtained from Tithicintāmaṇi and those calculated direct with the help of *Grahaṅghaṇa*, never exceeds 30 palas. I do not propose to describe the nature and scope of Tithi Cintāmaṇi\* for want of space. No such work was compiled by any one before Gaṇeśa Daivajñya. The work entitled *Makaranda* which has already been described before (page 127), helps quick calculations; but its method is somewhat different, and its date is Śaka 1400, still, Gaṇeśa may not have even seen it at all. Hence, there is no harm in giving full credit for originality to the author of the *Grahaṅghaṇa* or having produced a work like the *Tithi cintāmaṇi* which is so very useful in calculation and which reduces one's labour to the barest minimum.

#### Impeachment.

Kero Lakṣmaṇa Chātre has accused Gaṇeśa Daivajñya in the following works:—"He simplified calculations by employing easy devices.....but, because of this, the results became approximate to that extent and this laid the foundation of future erroneous methods.....Another result has been .....that the tradition of studying the Siddhānta works and of taking observations disappeared and the astronomers are deprived of the knowledge of the basic astronomical theory". There are also some others who accuse the author of the *Grahaṅghaṇa* in the same way. But while considering Gaṇeśa Daivajñya's work, it is no use accusing him for his approximate results by comparing his work with the modern European works. It should be considered what could be the best possible achievement with the means available in his time. Keroṇṇant Nāna and other critics do not seem to have considered this aspect of the question because there had been no means so far for judging the question whether earlier authors of *Karaṇaworks* could secure greater accuracy than Gaṇeśa or what original work was done by him with regard to the taking of observations. If the value of his work from this point

\*Keroṇṇant has, in his tables of Planetary Calculations, described the method of calculating tithi which is exactly the same as that given in Gaṇeśa's Tithicintāmaṇi. The underlying theory has not been explained. But the author has explained, in an article in the issue of the Indian Antiquary for April 1887, the theory underlying every step of the method together with an illustrative example.

\*\*Introduction to Keroṇṇant's Planetary Tables, P-2.

of view be estimated there would be absolutely no room left for accusing Gaṇeśa Daivajña. Again, if less laborious methods yield the same results as the extremely laborious calculations gave from Siddhānta works, why should not such methods be accepted? There is no harm in saying that Gaṇeśa was not at all inferior to earlier astronomers in securing accuracy of results for any problem even while attempting to simplify the work of calculation. Again it will be seen from the relation which the author has so far traced between all the Siddhānta and Karaṇa works, that Karaṇa was wrong in accusing Gaṇeśa of having laid the foundation of erroneous methods. If he means to say that the length of the year (adopted by Gaṇeśa) was inaccurate, the error had persisted from the very beginning. The author thinks that there were very few astronomers among the predecessors of Gaṇeśa in whom ingenuity and perseverance were so happily blended.

He was undoubtedly superior to Bhāskaraśārya in the matter of observations. Now-a-days the tradition of studying the Siddhānta works is almost lost. Not to speak of the Siddhānta works, one comes across very few astronomers who have thoroughly studied at least the *Grahalāghava* in its entirety. But this is not the fault of Gaṇeśa's works. Later history will show that he was succeeded by many more astronomers who understood the secrets of the Siddhānta works, who themselves compiled the Siddhānta works and who were also observers. Gaṇeśa himself has written a commentary on Siddhānta Siromani and Līlāvati. As regards compiling a work on theory, the work was already done by Bhāskaraśārya. It is of course true that he was not attracted to make new discoveries of the kind made in Europe in his time, but it is not proper to blame Gaṇeśa Daivajña on that account, for the zest for knowledge was, wanting among the people at large and, for several other reasons, the love of research had very nearly vanished.

### Commentaries

There is a commentary on the *Grahalāghava* written in Śaka 1508 by Gaṅgādhara of the Tapar Village. Mallāri Daivajña wrote his commentary in the year Śaka 1524. It contains the astrophysical theory. The *Viśvanāthī* commentary belongs to Śaka 1534. It contains illustrative examples. The commentary is also known as 'Udhāraṇa'. The last two of these commentaries are printed. Calculations are seldom made from the *Bṛhat Cīntāmani* because it contains too many tables; for this purpose of calculation people prefer the *Laghu Cīntāmani* which is printed. It is full of figures and the errors in these figures which have been accumulating for generations have now grown to an enormous extent. Most of the tables have been corrected. There is a commentary, Subodhini by name, written on *Bṛhat Cīntāmani* by Viṣṇu Daivajña, which expands the theory. Cīntāmani Kānu, a commentary on the *Laghu Cīntāmani*, is written by Yajñeśvara, an astronomer. It contains the theory. The commentaries on the *Muhurtaśāstra* and the *Vidhavanāśa* have been printed. Tārjanyāntara is a work meant to be used for ascertaining time. It is also called the *Pratoda yāntara*; it is commented upon by Sakharāma. There is another commentary by Gopinātha, a resident of Saṃgamaśvar. The name of Gopinātha's father was Bhairava and that of his grandfather was Rāma. This work will be further dealt with in the chapter on instruments. There are two other Gaṇeśas, different from the author of the *Grahalāghava*; one of them is the author of the *Tajak Bhūṣana* and the other of the *Jalakāṇṭhaka*.

## A legend

This account of the author of the *Grāhalaghana* will be closed recounting a legend after about him. Keśava, his father, once predicted the moment of an eclipse. The king of the country, who was a yavana, somewhat ridiculed him, as the prediction did not come true. Keśava was very much grieved over this. He, therefore, started a penance in the temple of Gaṇapati at Nandiagrama. He had grown old at that time. Looking to his sad plight and firm devotion, Gaṇapati told him in a dream that he (Keśava) would no longer be able to continue the work of observing and rectifying the positions of planets and that Gaṇapati would therefore himself come to birth as his son to do the work for him. Accordingly, a son was born to him, who was named Gaṇeśa. People at present regard him as an incarnation of God. Two more stories about him have already been told. All such stories indicate the reverence for him on the part of the people. If once an intelligent person comes to be regarded as divine incarnation, the feeling grows strong that his achievement can never be equalled and this very feeling has been mainly responsible for the absence of discoveries in our country.

## His Descendants

It appears that many of the descendants of Keśava and Gaṇeśa were also scholars. Ananta, Gaṇeśa's younger brother, wrote a commentary on Varāha Mihira's *Laghujātaka*, in 'Jaya' Sarpavatsara (Saka 1456), and Ananta claims that it is shorter and easier than that of Utpala. Ananta had been guided in his studies by his brother Gaṇeśa. It appears from the *Viśvanāthi* commentary that there was a commentary on *Grāhalāghava* by Nṛsiṃha, Gaṇeśa's nephew, but it could not be procured any where. Gaṇeśa had a son named Keśava, whose son Gaṇeśa wrote *Sitomanjuprakāśa*, a commentary on the *Siddhānta Sitomanj*. It may have been written about Saka 1520. A later descendant in his family, namely Keśava, son of Rūdra, compiled a work entitled *Lagna-kāla Pradīpa*, in Saka 1629, the name of the samvatsara being Sarvajit.

## KALPADRUMA KARĀṆA

A reference to this Karāṇawork occurs in the commentary on the *Karāṇa Kuṭubha*, written in Saka 1482. The commentary shows that the *Kalpadruma Karāṇa* was compiled by an astronomer, named Rāmācandra, and that he has mentioned a correction to be applied to the *Karāṇa Kuṭubha*. The figures, indicating corrections known as 'Rāmābija' which have been mentioned in the works of Dinkara and Srinātha to be described later on, are different from those mentioned by this commentator. From this it appears that the *Rāmābija* corrections mentioned in the works of Dinkara and Srinātha must have been different.

## LAKṢMIDĀSA—(Saka 1422)

He wrote a commentary, known as *Gaṇitātāvacintāmaṇi*, on the *Gaṇitādhyāya* and *Golādhyāya* of Bhāskara's *Siddhānta Sitomanj*. It contains 8500 verses, and gives theory and illustrative examples. His gotra was *Upamanyu*; *Vacaspati* is the name of his father; and Keśava, that of his grandfather. The Saka figure of 1422, adopted by him for the main example, has been taken by him as 'current'. The solved example on eclipse refers to the Kali elapsed year 4599 (i.e. Saka 1420). The reasons which led him to compile the commentary have been described by him in the following verse:—

शत्रुघ्नो विद्यते युवराजगणधिरतः सुहृद्विजयगणधिरकर्मणोऽवनीधिरतः ॥  
 शत्रुघ्नो विद्यते युवराजगणधिरतः सुहृद्विजयगणधिरकर्मणोऽवनीधिरतः ॥

Translation:—

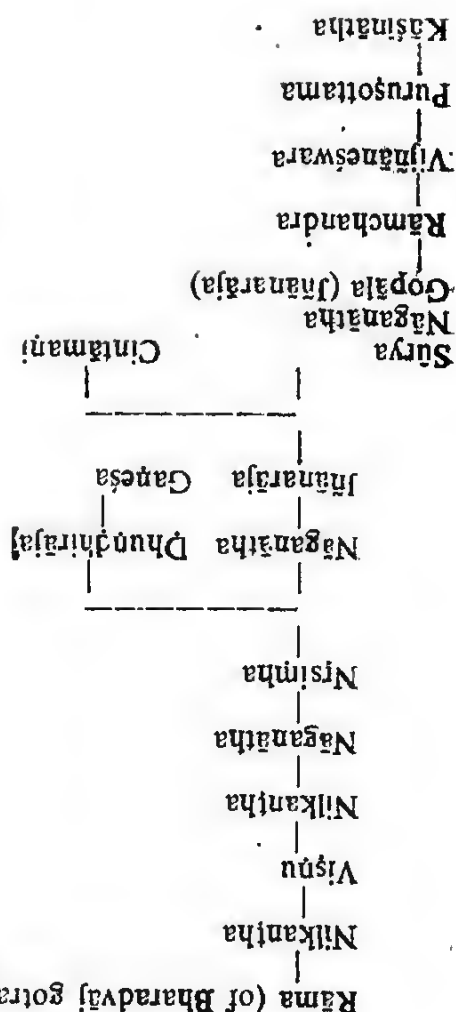
With a view to please the scholars, being instructed by Naganātha, requested by Devanātha, by Urvadhara, the younger brother and by all well wishers, the writer is making efforts to explain the Siddhāntasīromani.

Lakṣmidāsa appears to have been a good poet.

### JĀNARAJA—(Saka 1425)

#### GENEALOGY

Jānārāja was born in a famous family of learned men, which can boast of an unbroken tradition of scholar even to this day. A learned gentleman, from Bid in the Nizam State, and Kāśinātha Śāstri by name, once met the author at Bārī in Saka 1807. The author had taken notes of the brief history of his family which was told by Śāstri. Finding that it agreed with the family history of Jānārāja, he requested him by a letter recently (Saka 1817) for further information. He sent him some additional information and the genealogical tree. The genealogical table given in the margin has been prepared by the author on the basis of this information, and the note on Jānārāja in the 'Aufrecht' catalogue, and also on the basis of the information so far gathered by him. The names of only the first five ancestors of the family have been given from the Aufrecht's table. Even on this point the cross-references at three places in the catalogue showed some contradiction. The author has not ed the names which seemed most consistent with the context. The first man, Rāma, noted in the list has been pointed out in the Aufrecht Catalogue as flourishing at the court of King Rāma of Deogiri. In the genealogical table, sent by Kāśinātha Śāstri, the name of Nisimha's father has been stated to be Daivajñarāja and the list begins from that name. It appears that Naganātha or some earlier ancestor of the family might have received the title of Daivajñarāja. The family history recorded below will show that in the list of ancestors sent by Kāśinātha Śāstri, there must have been a break after Sūrya or before Gopāla.



According to the Aufrecht catalogue, Rāma was a resident of Pāṭhahpur. Sūrya Pandit who wrote Amṛta Kūpikā, a commentary on Bhāskara's Līlāvati, has described his father and grandfather in it. He observes,

अस्ति अस्मत्पुत्रस्तद्वत्पुत्रिणं च ग्राहतिवदभ्युपेतः  
 क्रीडानेन तस्मिन्नेव तस्मिन्नेव पाषाणिमथानं पुरं ॥  
 तत्राभ्युपेतमालोकितमः पृथुपथाः शीतानामनपाणिमथा  
 आरुह्यलङ्घितुं सर्वेषु परमप्राप्तेः द्विजनाथपतेः ॥ १ ॥

*Translation* :—“Parthapur, a village situated on the northern bank of river Godavari, about 2 miles away from the confluence of the Godavari and the Vidarbha, there lived a Brahmana astronomer, named Naganatha, belonging to Bhavadvy Gotra.”

In the commentary on Bhāskara's 'Bija' he observes :—

गौरीदेवतदण्डोत्तीर्णकटावासे तथा मंगला...  
मंगलामंगलमेतत् पवित्रमदिदं केशांतरं स्थितम् ।  
स्त्रीमन्त्राद्युदे बभूव.....श्रीनारायणाय नमः ॥

*Translation*:—(not necessary, since it carries the same sense as the above verses).

We find at present, a village named Pathari near the north coast of Godavari and about 70 miles to the east of Patana. This is the same as Parthapur. It is about 85 miles to the S.E. of Deogiri (Daulatabad). The river Vidarbha was probably known by another name Mangala. The above description shows that this Parthapur was about 2 miles to the N.W. of the confluence of this river and the Godavari. Kamalakara Daivajanya says while describing Pathari (See note on Vign later on) that the city was located in the Vidarbha country, and it was the capital city of kings and was situated 16 yojanas to the S.E. of Deogiri. Reckoning one yojana as equal to 5 miles, the figures 16 yojanas appear to be correct. Some other works written during this period have also named the country surrounding Pathari as Vidarbha country.

## DATE \_\_\_\_\_

The epochal positions which Jñānarāja has given in his work, Siddhānta Sundara, are true for Śaka 1425. This was evidently his date. Assuming 30 years for each generation, the date of Rāma, the first ancestor in the genealogical table comes to about Śaka 1215, and it agrees with that of king Rāma of Deogiri.

Jñanarāja has written a work on astronomy, called Siddhanta Sundara. I have seen the main parts of Siddhanta Sundara, viz., Golādhyāya and Gaṇitādhyāya. (Book No. 4350 in Anandaśrama). The Golādhyāya in it contains 6 chapters: 'Bhuvanakośa', 'Madhyagatihetu', 'Chedyaka', 'Mandālavarmāna', 'Yantramālā and 'Rituvarmāna'. It contains respectively 79, 30, 21, 16, 44 and 34 verses. The Adhyāya on 'gaṇita' (mathematics) contains the following *Adhikāras*:—Mean places, true places, three problems, probability of eclipses, lunar eclipse, solar eclipse; risings and settings of planets, shadow of stars.

The Siddhanta Sundara, follows the modern *Sūrya Siddhānta*. Like a *karaṇa* work, it gives the epochal positions of planets and annual rates of motion for finding the planets' places. The epochal positions are true for Śaka 1425. The moment for which they are true is not mentioned. But the author has found from actual calculation that they have been calculated for the moment of 56 ghatis 39 palas after sunrise on Thursday, the 8th lunar day of the bright half of Āśvin in that year. These positions and the rate of yearly motion of the planets, completely follow the modern *Sūrya Siddhānta*. The epochal positions appear to have been given for an odd moment. But the mean longitude of the Sun in it is  $6^{\circ} 0' 14'' 17''$ , which shows that it is true for a moment exactly 15 ghatis after the mean *Libra* Ingress. From this, this object seems to give the positions for 15 ghatis after the mean *Libra* Ingress. A correction to planetary places has been mentioned in the chapter on mean places.

—: translation:

Jhannaraja does not appear to have mentioned the ayanamsas of his time. He has simply explained the term 'ayanamsa' as the difference between the sun's

\*Sudhakar Dvivedi, teacher of Mathematics at the Banarshi College, Varanasi wrote a book entitled, *Ganita Dvayam*, in Banarshi in Sanskrit in 1814 has been printed. See page 66 of the book. The book contains an account of astronomers.

position calculated from the shadow cast by the noon sun and that obtained from 'calculation' based on a Karana work. The annual rate of equinoctial motion has been said to be 1'. He has also given the method of finding ayanamsa as described in the Surya-Siddhanta. The rate of annual motion when calculated by it comes to 54".

Jñanarāja, after mentioning the opinion of the Śrutis and Purāṇas about the increase and decrease of the moon's digits, observes, in the chapter on the elevation of the moon's cusps :—

इहं वृत्तः पृथक्कृतः क्षितिर्दत्त एव पृथक्क्षितिः क्षतिः ॥  
क्षितिर्दत्तं च क्षतिर्दत्तं ॥ १५ ॥

Translation :—

"The sun's rays themselves are known in the Vedas as Gods. They gradually add the objects to and carry them away from the moon in the bright and dark half of the month."

The Sundara-Siddhanta gives nothing new as established by observation. Some explanations of theory, however, are different from those of Bhāskara. The chapter on Yantramālā describes one new instrument. There is no harm in saying that the work Siddhanta-Sundara is on the whole beautiful as the title suggests.

#### Other Works

Sūrya has recorded in his commentary on Bhāskara's Bijagāṇita that Jñanarāja has, in addition to the Siddhanta, written a work, on each of the following subjects : astrology, rhetoric and music.

#### Account of Descendants

An account of his descendants Dhruvāhīrāja, Gaṇeśa and Sūrya has been given for each separately later on. It has been already mentioned before, that Cīntāmāni wrote a commentary on Sundara-Siddhanta. Here the author gives an account of some of the remaining descendants on the basis of the information supplied by Kāśinātha Śaṣṭi. It is not known when this family shifted from Pāṭhar to Bid for permanent residence. Bid is a place about 50 miles to the W.S.W. of Pāṭhar, and about 60 miles to the South of Daulatabad and 50 miles to the S.E. of Pāṭhāṇa. Nāgaṇātha has compiled a commentary named Narapati jayacārya. Purnasottama has written Kēśavi Prakaśa and Varga saṃgraha, two works devoted to astrology and written another work entitled Datta Kutubhala. He writes in the Kēśavi Prakaśa that Rāmācandra was proficient in the science of astrology and that Vijānēśvara was a scholar of logic, grammar and astronomy, and was honoured by king Baji Rao. This Baji Rao was the last Pēṣwa (Saka 1717 to 1739). Kāśinātha Śaṣṭi is still living and he is a scholar of logic, grammar and astronomy. He is the highest officer at Bid. He is very much honoured in the Hyderabad State. He has been honoured by the Saṅkarācārya of Hampi Virupakṣa, who conferred on him the title of Śūri Cūḍāmāni. He has compiled a work entitled Nyāyāpōta and is engaged in writing the work Śrī Devi Bhāgavat Cūṭṭika, of which he has compiled five chapters.

## Surya (Birth Saka 1430)

He was the son of Jñanarāja, the author of *Siddhanta-Sundara*. He has written a commentary on Bhāskara's 'Bija' in which he has called himself *Suryadāsa* and the work, *Sūrya Prakāśa*. He has stated that he wrote the commentary in Saka 1460, that is in his 31st year. From this, his birth year comes to either Saka 1429 or 1430. This commentary contains 2500 verses. At some places he has given his name simply as "Sūrya". He has written a commentary, *Gaṇitāmṛta Kūpikā* on Bhāskara's *Līlāvati*. It belongs to Saka 1463. The theory in it has been explained by numerical quantities, and regarding the work *Līlāvati* as a poem, he has given several interpretations of some of the verses in it. This commentary contains 3500 verses. Both these works have a verse given at the end which cites the names of eight works written by him. They are :—

*Līlāvati Tika*, *Bija Tika*, *Śrīpāṭipaddhantigaṇita*, *Bijagaṇita*, *Tajikagaṇita*, *Kāyadāwaya*, and a work on metaphysics entitled *Bodhasūdhakara*. The fourth of these, *Bijagaṇita*, is his own independent work. The title of the *Tajika* work is *Tajikāṇkāra*. There is a copy of the work in the Deccan College Collections. This copy also contains the above mentioned verse, though the word 'Kāyāśṭaka' is found there in place of 'Kāyadāwaya'. Even the information sent by *Kāśinātha Śāstri* reveals that *Sūrya Paṇḍit* compiled 'Kāyāśṭaka' and the names of the 8 works are given thus. 'Padya-mptataraṅgiṇī'; *Rāmakaṣṇa Kāvya*, *Sanakaraḥaraṇa*, *Nṛsiṃha Campu*, *Vijñāna Mocana*, *Bhagavattigita* etc. The poem 'Rāmakaṣṇa Kāvya' is well known and its verses are capable of double interpretation, one of which applies to Rāma and the other to Kṛṣṇa.

Colebrooke writes, "He (*Suryadāsa*) was the author of a complete commentary on the *Siddhanta Śironant*, and of a distinct work on Calculation, under the title of *Gaṇitāmālā* and of a compilation under the name of *Siddhanta-Saṃhitā-Sar-Samuccaya*, in which he makes a mention of his commentary on the *Śironant*". These three works have either been included in the above-mentioned verse enumerating his works, or in the information sent by *Kāśinātha Śāstri*, nor have they come to the authors' notice. The *Aufrecht* catalogue recording the names of works written by *Sūryasuri* or *Sūryadāsa* or *Sūrya*, include the names of the above three works, and most of the works mentioned earlier, and also the following additional works :—

*Graha Vinoda*, *Kavi Kalpalata Tika*, a commentary on *Bhagavadgītā* entitled *Paramārthapara Bhaktiśāla*; *vedānta Śata Sloka Tika* and a commentary on *Amaru Śataka*, named *Śiṅgāra Tarāṅgiṇī*.

On the whole, it seems that *Sūrya* had been a very great scholar. He was fully justified in speaking of himself in his *gaṇitāmṛtakūpikā* as 'a worthy pilot on the ocean of mathematics, an expert in prosody, rhetoric and music, and can adopt in high-class literature.' In the work "Gaṇitāmṛta Kūpikā" he makes the following statement about himself :—

"*Aham Sūryabhidhānāḥ Kavīḥ swapradyāpārīṣmatāḥ Līlāvatiṃ vyākhyātum vithādaroṣm*".

"Miscellaneous Essays, 2nd edition, Vol. II, p. 251. I have stated on page 144, on the basis of Colebrooke's statement, that *Suryadāsa's* commentary on *Līlāvati* belongs to Saka 1460. But that is a mistake. I got the correct information, about *Suryadāsa* after that page was printed. The Saka should be 1463.

Translation:—

"I, Suryadāsa, have ventured to write a commentary on Līlavati, on the strength of the intellectual power possessed by me." He further adds,

निर्दय्य जीवन्निर्वाण्यमप्यनिरुद्धसप्तमसमयमिदं मया यत् ॥  
तत्समष्टय गणितार्थवर्णनैः टीका निरूप्यते दृढवर्तिदेववृत्तैः ॥

At the beginning of his commentary of Bijā, he remarks.

यथादिबुद्धेभ्यस्तत्त्विकोसंज्ञावर्णनोपादहे पाटीकुट्टकबीजवर्णनोपादरेणमः ॥  
सुदृढं तत्त्विकोत्पत्तिकमहे (?) संगीतशास्त्राधिवे  
तं तदे निजवर्णनमगुणं श्रीमानराजं गृहे ॥ २ ॥

Still, at the end he observes,

तदर्थः (शान्तराज्यम्) मुद्राय मुक्तवर्धिवत् प्रीत्य जीवाम्य ॥  
एके मुद्रकस्य समतिप्रेषणादितः प्रीयति ॥ ३ ॥

It appears from this that though he acquired knowledge from his father Jñānarāja, his work was mainly the outcome of his own intellectual wealth.

#### ANANTA—1447

He compiled 'Anantasudhārāsa', a work on the calculation of the *Pañcāṅga*, in Śaka 1447. It follows the *Suryasiddhānta*. Ananta remarks in the beginning.

दुर्लभापिप्रकर्षणार्हे मुद्रयादयं मया ॥ मुक्तवर्धिवर्धये तत्रै श्रीकान्तजीवितः ॥

From this, the name of his father appears to be Śrikānta. The author has not seen the work himself. He has stated this from (the information given in) the *Gaṇakatarāṅgi* by Sudhākara. Sudhākara says that it was a work consisting of tables and that, Nārāyaṇa was the author of *Muhūrtamārtāpā*, his father's name was Ananta, and Ananta's father's name was Hari (see the account of Gaṅgādhara, Śaka 1502, given later on) and Śrikānta, the name of the father of this Ananta, also is an epithet of Hari, and the dates of both of them appear to agree. From this, he (Ananta) seems to have been the father of the author of *Muhūrtamārtāpā*. But there is a commentary, *Sudhārasasakaśaka*, on Ananta's 'Sudhārāsa', by Dhruvadhīrāja, and according to Auriecth's catalogue, a part of this work called *grahāṇodāya* is in the library of the Sanskrit Pāṭhaśālā at Vārāṇasi.

From this it appears that this is a kāraṇa work containing tables useful for *Pañcāṅga* calculation. An account of the family occurs at 2 or 3 places in the works compiled by Nārāyaṇa, the author of *Muhūrtamārtāpā*, and by Gaṅgādhara, his son (Page 150). It is mentioned every where that Hari is the name of Ananta's father and not Śrikānta. They give much information about Ananta but nothing about his works. This leads the author to doubt if this Ananta was really the father of the author of *Muhūrtamārtāpā*.

## PHUNDIRAJA

From the family history given by him in his work, *Jatakabhāṣa*, and by his son Gaṇeśa in his work *Tājikabhāṣa*, it becomes evident that he was the resident of Parthapur (Pāthari), situated to the north of Godāvari, near Devagiri (Daulatabād). He has stated Nṛsiṃha to be his father's name. The author has, on the basis of the genealogical table sent by Kāśinātha Śaṣtri, recorded him as the son of one Nṛsiṃha whose name appears in the genealogical tree, printed on page 140 in his account of Jānaraṇa. From this, Phunḍhirāja would be the uncle of Jānaraṇa, the author of the *Sundara Siddhānta*. But Phunḍhirāja has offered salutations to the preceptor Jānaraṇa at the beginning of his work *Jatakabhāṣa*. This leads one to suspect that Jānaraṇa, his preceptor, might have been different from the author of *Siddhānta sundara*, or else, Phunḍhirāja might have been the son of some other Nṛsiṃha of the same family. Phunḍhirāja has written a commentary 'Sudhārasakaraṇacāṣaka', on *Sudhārasa*, a *karāṇa* work, by Ananta; similarly, according to Aufrecht Catalogue, the works, *Graha-lāghava-Udāharaṇa*, *Graha-phalopapatti*, *Pañcan-gaphala*, and *Kuṇḍakalpatala*, were compiled by him. If this Phunḍhirāja be the same person as Phunḍhirāja, the author of the *Jatakabhāṣa*, his date must have been later than Saka 1447. Vivanaṭha (Saka 1551) has referred\* to the *Tājikabhāṣa* by Gaṇeśa, son of the author of the *Jatakabhāṣa*. It follows from this that the date of compilation of the *Jatakabhāṣa* must have been earlier than Saka 1500\*.

Phunḍhirāja's work *Jatakabhāṣa*, is very famous and it is now printed. It appears from the *Jatakabhāṣa* that Phunḍhirāja's uncle compiled a work on astrology. The name of this uncle and that of his work are not known. Gaṇeśa's work, *Tājikabhāṣa*, is also well known. It is recorded in Aufrecht's Catalogue that Gaṇeśa had another work, *Gaṇita Manjari* to his credit.

\*Vivanaṭha-remains in his commentary on the *Tājika Nīlakaṇṭhi* that the statement of the author of *Tājikabhāṣa* viz. "Jānakaṇṭhaṁbhūti" is wrong; and his view is correct.

\*\*Further information was received from Kāśinātha Śaṣtri after 272 pages of the book were printed. Its summary is given below:—

"Phunḍhirāja carried on his studies under the care of Jānaraṇa himself. The Saka years of birth and death of the descendants, beginning from Sūrya are as follows:— Sūrya 1429-1510; Nāganaṭha 1480-1537; (Gopāla 1543-90; Jānaraṇa, birth year 1595; Rāma's death 1731; Vighṇeśvara 1712-1769; Puruṣotama 1748-1799; Kāśinātha, birth year, 1768. Nāganaṭha the son of Sūrya had received the title 'Kāṇasūra' from the Delhi Court. He compiled the work, entitled 'Narpatī-jyāośārya', Kāśinātha Śaṣtri received the title *Satīdāmaṇi* in Saka 1813. Instances are found in which the uncle is younger than the nephew; and hence it is not impossible that Phunḍhirāja studied under the care of Jānaraṇa and in that case the date of compilation of *Jatakabhāṣa* would come to somewhere between Saka 1430 and 1460 and that of *Tājikabhāṣa* Saka 1480. Nāganaṭha whose name written below that of Sūrya in the genealogical table was Sūrye's son; (Gopāla and Jānaraṇa are different persons, and there might have been one person each between Nāganaṭha and (Gopāla and Jānaraṇa) that the above-mentioned Saka years are quite reliable. But in the absence of the correct date he has noted them here for what they are worth. Nāganaṭha may have received the title of 'Kāṇasūra' in the reign of Akbar or Jehangir. There is an ancient work, entitled *Narpatī-jyāośārya*, written in Saka 1097 and hence, I have presumed that Nāganaṭha wrote a commentary on *Narpatī-jyāośārya*, but it is not known if Nāganaṭha had actually written an independent work of the same title.

## ANANTA

Ananta wrote a commentary on '*Kāmadhenu*', a work devoted to the calculation of tithi and other parts of the almanac; and Ananta has written a commentary on it. The work, *Kāmadhenu*, was compiled in Saka 1279 by Mahādēva, son of Bopadēva, a resident of Tryambaka on the bank of Godāvarī. It contains tables for calculating tithis etc. according to Brahma-pakṣa and Aryapakṣa. The sons of this Ananta namely Nīlkantha and Rāma, compiled works in Saka 1509 and 1512 respectively. From this, the date of Ananta's commentary on *Kāmadhenu* comes to about Saka 1480. The *Jātakapaddhati* is an astrological work written by Ananta\*.

## FAMILY HISTORY

Rāma, the son of Ananta has recorded his family history in the conclusion of his work, *Muhurta Cintāmaṇi*, as follows :—

आशीर्वादपूरे पञ्चम्यामाष्टमेतिहोमसिद्धिः । अतीतिवर्तिनः फलितरिषे मये कृतमित्यमः ॥  
 शतवत् तत्पञ्चम्यामितिहोमसिद्धिः । तत्कृतवर्तिनः फलितरिषे मये कृतमित्यमः ॥  
 स विवर्तिनः ॥ ८ ॥  
 अतीतिवर्तिनः फलितरिषे मये कृतमित्यमः ॥  
 अतीतिवर्तिनः फलितरिषे मये कृतमित्यमः ॥  
 अतीतिवर्तिनः फलितरिषे मये कृतमित्यमः ॥  
 अतीतिवर्तिनः फलितरिषे मये कृतमित्यमः ॥

The author is giving his genealogical table below on the basis of this account and from the history given by his descendants in their works. His gōra was Gārgya. He was a resident of Dharmapuri, in Bidarha, in the valley of the Godāvarī. Ananta left the place for Vārānasi where he resided. His descendants also used to reside at Vārānasi.

Cintāmaṇi (Gārgya Gōra)

Ananta (Padma his wife)

Nīlkantha (Candrikā his wife) Saka 1509  
 Rāma, (Saka 1512, 1522)

Govinda (Gomati his wife)  
 Birth Saka 1491

Mādhava  
 Saka (1555)

\* The author has not seen Ananta's works but he has described his work on the basis of the accounts given by his descendants and the *Gangāka Tarangini* by Sudhākara.

*History of Descendants*

From the account given by Rāma and Nīlkantha, Cintāmani appears to have been an astronomer and a great scholar. Ananta's account has already been given above.

The name of Nīlkantha's mother was Padma. He has compiled a work entitled *Todarānanda*. Descriptions of this work occur in other works, from which it appears that the work contained all the three branches of astronomy, Gāṇita, Mūhūrta and Hora; and even Mādhava, the grandson of Nīlkantha has supported this surmise. The author of *piyūṣadhara* (commentary) writes that it treats the risings and settings of planets in the chapter Candraravāṭavilāsa and deals with Nyūṣadhimāsa (suppressed and intercalary months) in the chapter called Kālāśuddhisaukhyā. The author has seen a part of the book (No. 5088 in the Anandaśāstrama); which contained only the section on Mūhūrta. It contains a large collection of excerpts from earlier writers. The number of verses in the portion seen by him is about 1000; it contains a chapter on pilgrimage only and that too is incomplete. It appears, therefore, that the work must have been very voluminous. It may have received the name Todarānanda after Todarmalla, the minister of Akbar. Nīlkantha was a great follower of Mīmāṃsā and a scholar of *Sāṅkhyā* Śāstra and as described by his son Govinda, was Paṇḍitendra, (the leader of Paṇḍits) at the court of Emperor Akbar. Nīlkantha compiled a work *Samāntara*, (Varṣāntara), on Tājik which is also known as *Tājika Nīlkanthi*. The work is very famous and has been published along with different commentaries. Nīlkantha compiled it in Śaka 1509. Viśvanātha has written a commentary on it with examples. It belongs to Śaka 1557. The Aufrecht catalogue mentions the following additional commentaries on it:—

The Dvighaṭika, another by Lakṣmipati and the third entitled the Śrīphala cardini by Śrī Hara. Other commentaries have been described below. Nīlkantha has compiled a Jātakapaddhati, which contains 60 verses. According to the author of the *Gaṇakāntarāngī*, the system (embodied in this work) is well known in the province of Mithilā. According to Aufrecht Catalogue, Nīlkantha has compiled the following astronomical and astrological works:—  
*Tiṭhi Ratnamālā*; a work on Horāry astrology entitled *Praśna Kaumudī* or *Jyotiṣa Kaumudī*; *Daivajñā vallabhya* and a commentary or Jaimini Sūtra called Subodhini. From the same catalogue it appears that Nīlkantha also wrote commentaries on Graha Kautuka, Graha Lāghava, Makaranda and on a Mūhūrta work.

The account of Rāma will follow later. Govinda, Nīlkantha's son, has written *Piyūṣadhara*, a commentary on Mūhūrtacintāmani. It is very extensive and famous. He compiled it at Vārāṇasi. In that work he states that Mātūpur, in Vidarbha, was his place of residence. Perhaps, Dharmāpur itself may have Mātūpur as its second name. Govinda was born in Śaka 1491. His mother's name was Candrika. He wrote the commentary, *Piyūṣadhara*, in Śaka 1525. He also wrote the commentary, *Rasala*, on *Tājika Nīlkanthi*. It was written in Śaka 1544. The commentary, *Piyūṣadhara*, reveals great ingenuity on the part of Govinda. But while in his commentary on the 9th verse in the chapter on Samkrānti, he observes, "Eclipses are falsified if one follow the Sāyana system of calculation. A



computed from Brahma Siddhanta, together with the corrections mentioned by the *Rājamṛgāṅka*. The work describes only the method of finding the true places of planets. The total number of verses (in it) is 46. It appears that the works used to be accompanied by tables; but they were not found in the copy seen by the author. But one cannot do any calculation without such tables. The writer calls this work *Laghu Khetaka Siddhi* which indicates that he may have written another work called *Bihai Khetaka Siddhi*. Some verses attributed to Dinakara are given in the commentary on the *Mahādevī Sāraṅgī*, but they are not found in this work. This also lends support to the surmise about the existence of a larger work. The writer has given his own account in the words.

श्रीमदानीं कौशिकं शक्तिशक्तिमयं दक्षिणं शक्तिशक्तिमयं ॥

जानि यम शक्तिमयः शक्ति शक्तिमयः शक्ति शक्तिमयः ॥ ३१ ॥

शक्तिशक्ति शक्तिमयः शक्तिमयः शक्तिमयः शक्तिमयः ॥

शक्ति शक्ति शक्तिमयः १५०० शक्ति शक्तिमयः १६३५ शक्ति शक्तिमयः १६३५ ॥ ३२ ॥

The *Candārka* consists of only 33 verses and deals only with the calculation of the true places of the sun and moon.

This work also takes Śaka 1500 as its epochal year. It appears that the work may have been accompanied by tables giving the equation of centre for finding the true place of the sun and moon; and then these are to be used for calculating tithi and other parts. From this it appears that the *Laghu Cintamani* tables of Gaṇeśa Daivajñya were not in use in Gujerat in those days.

A correction stated to be in use in Gujerat is mentioned in both the works. The same correction is found also in the *Graha Cintamani* to be described (on page 151) later, and in the commentary on the *Mahādevī Sāraṅgī* at some places, it is called 'Ramabija'.

### GANGADHARA (Śaka 1508)

Ananta  
Kṛṣṇa  
Hari  
Ananta  
Nārāyaṇa  
Gangādhara

In Śaka 1508 he wrote Manorama, a commentary on Graha Laghava. He was the son of Nārāyaṇa, the author of Mūhūrta Mārtaṇḍa. The genealogical table, given in the margin, is based on the information given by both the authors. The *Mūhūrta Mārtaṇḍa*, was compiled in Śaka 1493, and the author has given in it his family history. From this it is learnt that he was a Vajrasenī Brahmana belonging to Kausika gotra. He was a resident of Jāpar, a village situated to the north of the famous temple of Śiva (Chişṇēśvara) which lies to the north of Devagiri (Daulatabad), and his ancestors were originally residents of Sasamanur. There is a village, Verul, situated about 4 miles from Daulatabad, and the deity there is at present known as Chişṇēśvara. Janardana Hari Aiyar has published the *Mūhūrta Mārtaṇḍa* along with its Marathi translation. He writes in its introduction that, on enquiry at the village Jāpar and its neighbourhood, he came to know that the descendants of the family of his maternal uncle only are now surviving.

## RĀMABHĀTA (Śaka 1512)

He has written a karāṇa work entitled Rāmavinoda. It has adopted Śaka 1512 as the epochal year, and the length of the year, the epochal positions and motions of planets, are based on the modern Surya Siddhānta. The corrections to be applied to planets' motions are the same as those mentioned before (page 45) Under orders of Śrī Mahārāja Rāmadāsa, a minister of Akbar, Kāma Bhāṣa compiled\* the Rāmavinoda in year 35 of the Akbar era 35 (i.e. Śaivahana Śaka 1512). It contains 11 chapters and 280 verses. Viśvanātha has written an illustrative commentary on it. Rāma has compiled a small volume of tables devoted to the calculation of tithis etc., containing 17 verses, which form a part of the work; and Sudhākara Dvivedi says, that people on Jaipur side compile their almanacs with the help of this work.

His well-known work Muḥurta Cintāmaṇi was written in Śaka 1522. It was compiled at Vārāṇasī. The author himself has written a commentary on it entitled 'Pratītiśāra'. In addition to this there is the famous commentary, Piyaśadharā, on it, written by his nephew Govinda. Both these commentaries have been printed.

His family history has already been given (page 147) under the account of Ananta.

## ŚRĪNĀTHA (Śaka 1512)

He wrote a Karāṇa work, named *Graha Cintāmaṇi* in Śaka 1512. It describes the method of calculating planets' places from 'Vaiṣṇava'. The work appears to have been accompanied by tables. They were not found along with the copy seen (Deccan College Collection No. 304 of 1882-83). The work is of no use without them. The work neither gives any epochal positions nor any clue to ascertain the school (pakṣa) to which it belongs. The work has two chapters and even includes the section on astrology. The name of Śrīnātha's father, was Rāma\*\* and that of his elder brother, Raghunātha.

## VIṢṆU

There is a well-known village named Pāṭhari in Bidarḥa. It has already been described on page 141. There is a village Golagrāma, near the northern bank of the river Godavari and 2½ yojanas (about 20 miles) to its west. A very well-known family of scholars lived in that village. The family shifted to Vārāṇasī later on. It produced a number of authors and Viṣṇu was one of them.

He compiled a Karāṇa work. It has adopted Śaka 1530 as the epochal year; it belongs to Saurapākṣa. He has in addition written a commentary named *Subodhini* on the *Bīḥat Cintāmaṇi* by Gaṇeśa Daivajña, the author of the *Graha Laghava*. It explains the theory also. The study of such commentaries proves very useful for the compilers of new works on astronomy. His brother Viśvanātha has written an 'Udāharaṇa' on his Karāṇa work. In his *Muḥurta* (Uddamaṇi, Śiva informs that Viṣṇu was the 'Jagatguru' (world teacher). In

\* According to Dr. Bhāṇḍārkar (Report on the search for Sanskrit Manuscripts 1883-84, Page 84) it was compiled in Śaka 1536; but that is an error.

\*\*Prof. Bhāṇḍārkar remarks that this Rāma may probably be the same as Rāma, the author of Muḥurta (Intāmaṇi) (Report on the search for Sanskrit Manuscripts 1882-83, page 88). But the account of Rāma, the author of the *Muḥurta Cintāmaṇi*, given above, will show that it is an impossibility.

addition to this, some more account of the author will be found in the following verses by Visvanātha.

The famous commentator Visvanātha, and Kamalākara, the author of Siddhanta tattva were born in this very family. The following verses appear in a detailed account of his family given by Kamalākara :—

अथ सप्तविंशत्यं २०।३० संक्षुब्धशक्तिं च दर्शयाम् ॥  
 गदावतीसिन्धुविमानसंस्थं ह्यं च पदेवगतिं नाना ॥ १ ॥  
 प्रसिद्धमस्मान्मप १६ योजनैः प्रपञ्चाभ्यामवस्थितसिन्धुतटपथटी च ॥  
 विदुषदेशातिरगतिस्तस्या राशौ पृथी तद्वेगनदेशमप्य ॥ २ ॥  
 तस्यास्यै किमिष्यरथान एव सप्तविंश २ ॥ गुरुषुः किम योजनैरेव ॥  
 गदिवातीसिन्धुविमानसंस्थं ह्यं च पदेव गतिं नाना ॥ ३ ॥  
 अस्याः सप्तौ सप्तविंशत्यपकटे प्रपञ्चिते गतिमिष्यया प्रसिद्धः ॥  
 तथैव यस्यां पृथ्वीतमस्य पृथी तथोत्तरस्यां स्वयं सौ ॥ ४ ॥  
 गदावतीसिन्धुविमानसंस्थं ह्यं च पदेव गतिं नाना ॥ ५ ॥  
 तस्यास्यै किमिष्यरथान एव सप्तविंश २ ॥ गुरुषुः किम योजनैरेव ॥  
 गदिवातीसिन्धुविमानसंस्थं ह्यं च पदेव गतिं नाना ॥ ६ ॥  
 अस्याः सप्तौ सप्तविंशत्यपकटे प्रपञ्चिते गतिमिष्यया प्रसिद्धः ॥  
 तथैव यस्यां पृथ्वीतमस्य पृथी तथोत्तरस्यां स्वयं सौ ॥ ७ ॥  
 गदावतीसिन्धुविमानसंस्थं ह्यं च पदेव गतिं नाना ॥ ८ ॥  
 तस्यास्यै किमिष्यरथान एव सप्तविंश २ ॥ गुरुषुः किम योजनैरेव ॥  
 गदिवातीसिन्धुविमानसंस्थं ह्यं च पदेव गतिं नाना ॥ ९ ॥  
 अस्याः सप्तौ सप्तविंशत्यपकटे प्रपञ्चिते गतिमिष्यया प्रसिद्धः ॥  
 तथैव यस्यां पृथ्वीतमस्य पृथी तथोत्तरस्यां स्वयं सौ ॥ १० ॥

Translation :—

- (1) On the northern bank of Godavari is situated the fortified town called Devagiri, whose latitude is 20°-30'.
- (2) The city of Pāṭhārī, which is 16 yojanas from this town and in S.E. direction is the capital of Vidarbha and is situated in the middle of the country.
- (3) At a place, a little West to this city and about 2½ yojanas away, is a spot on the bank of the Godavari, where the river Ganges is regarded to have come to stay with the request of Gautama.
- (4) On the northern side of this river there is a village named 'Gol' and on the southern side is a village named Puruṣottama, the river flows between the two.
- (7) There lived in the village of Gol, on the northern bank of Godavari, a Mahārāṣṭrian Brāhmaṇa, named Rāma belonging to Bharadwāja gotra.
- (8) His son, Bhaṭṭācārya became very famous as a scholar of astronomy and he (Bhaṭṭācārya) got a son, Divākara, by the favour of God Gaṇeśa whom he used to worship.

Rāma was an astronomer; Bhaṭṭācārya was a follower of 'Mīmāṃsā' and a logician. Divākara was a great astronomer and a disciple of Gaṇeśa Daivajñāy, the author of the *Graha laghava*. Such is the information that one can gather from the family history written by Visvanātha, Nṛsiṃha, Mallārī and other descendants of his family.

Divākara had five sons. Visvarāṭha has paid a fine tribute to their erudition and character in his commentary on Tājika Nīlkanṭhi. Visvanātha himself was the youngest of the five. The description runs thus :—

दिव्याकरी नाम अथैव विद्वान् दिवाकरायाम् गतिर्ये सत्ये ॥

स्वकल्पितेन विदुषेन वैदुष्यमगदृशितविरक्तम् ॥ २ ॥

Summarized translation\* :—

\* In translating these verses, the author has omitted the translation of various lengthy poetic epithets used for the astronomer simply for the sake of composition, since these have nothing to do with the history of astronomy.

The following verses by Kamalākara which follow those given above state the history of this family as follows:—

अस्यायं वंशस्य विवाकरस्य श्रीगुरुदेवस्य इति प्रसिद्धः ॥ ९ ॥  
 तज्जगत् प्रदीपविदीपं वीर्यं नृसिंहेनामा गणकायुधैः ॥ १० ॥  
 वंशं धनाय च सौम्यस्य विद्वान्मणोर्वीरकर्मसु च हि ॥  
 स्वायं पराय च कृतं त्वय्युदयविजयसु प्रदीपविजयं ॥ ११ ॥  
 तज्जगत् तस्यैव कृतं त्वयैव स्वयं प्रदीपविजयं ॥  
 सविस्मयविजयैः प्रदीपविजयैः गणकायुधैः ॥ १२ ॥  
 दृग्गोलसंज्ञावर्तमानयुगवत् प्रदीपविजयः श्रीकर्मणोः ॥  
 मयस्य विजयविजयविजयसु विजयं सौम्यं ॥ १३ ॥  
 स्वयं त्वयैव १५८० शकेष्वतीति विजयविजयसु मयं ॥  
 मणोर्वीरस्यैव विजयविजयसु मयं ॥ १४ ॥

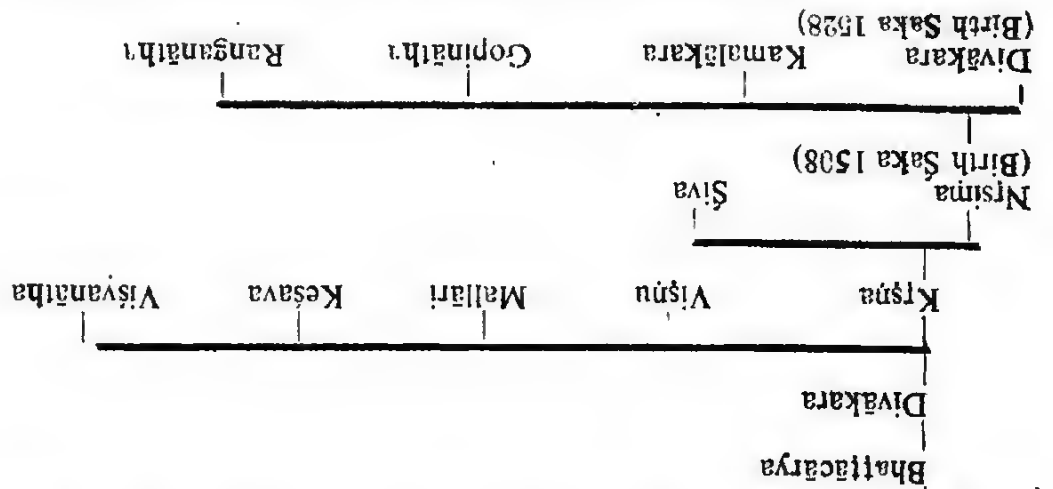
Translation:—

(9 & 10) This talented Divākara had a famous son, the astronomer Srikṣṇa, who, in his turn gave birth to a son, Nisīmha, who was well versed in the knowledge of the 'sphere' and honoured by astronomers.

(10) He compiled a commentary on the Śiromaṇi, and one on the *Sūrya siddhānta* and a work explaining the sphere and motions of planets. (11 to 14) Divākara, who was his preceptor in the astrology, compiled the above mentioned works on astronomy, including the new theory of spherical areas. This work was intended to be a standard work, explaining all theories about 'gol and siddhānta and was named 'Siddhānta, tatvavivēka'. He compiled this siddhānta work in the Śaka year 1580, at Vārāṇasi which is situated on the northern bank of the river Bhāgirathi (Ganges).

The genealogical table prepared from this description and other information, is given below:—

Rama (A Mahārāṣṭra Brāhmaṇa of Bhāradvāja gotra and Taittiriya Branch).



Mallāri has stated that his family deity was Mallāri. In his commentary on Śrīmān, written in Śaka 1543, Nṛsiṃha states that Divākara died at Vārāṇasī. He was the direct disciple of Gaṇeśa Daivajñya, and from this it seems that he must have been in South India till about Śaka 1500. The works compiled by the members of this family after Śaka 1533 were written at Vārāṇasī. From this it appears that this learned family shifted to Vārāṇasī within 25 to 30 years after Śaka 1500. None of them seems to have received actual patronage at the Delhi Court; they are, however, described as being honoured by kings.

Mallari was born in the famous family described by Visnu above. He has written a commentary on the *Grihalagana*. He has described in it the date of this commentary in a strange way, thus :—

*Translation*.—The astronomer, Bāla, wrote this commentary in the Śaka year, denoted by 1547 diminished by the sum of the numbers denoting the month, the nakṣatra, the day of the week, the lunar day, and the half month. The month was the number which is the square root of "the current śaka year reduced by 5 and divided by 31" i.e.  $\sqrt{\frac{1524-5}{31}} = \sqrt{\frac{49}{31}} = 7$ . The nakṣatra was equal to the month plus 5 i.e. 12th. The day of the week was equal to the nakṣatra reduced by 10, hence 2 or Monday; the lunar day was the 1st and Pakṣa was the 1st.

Mallāri has explained the theory of *Grahālaghava* in the commentary. The task of explaining the theory of a work like the *Grahālaghava* can be said to be even more difficult than that explaining the theory of a *Siddhanta* work. But they accompanied the work with great success.

*ṛāṇa + month + tithi + pakṣa + day of the week + nakṣatra.*

He was a commentator like Bhaṭṭopāya. He was the son of Divākara of Golaṅkāma. His family history can be found from the account given by Viṣṇu. He has recorded the date of his commentary on *Tagakarāṇikāṇṭhi*, as below :—

॥ १४४ ॥ अथ चैवमपि नृपतिविरचितं ॥  
मन्त्राणां विनियोगः ॥

“This was completed by Visvanātha on the 5th lunar day of the bright half of Mārgasīrṣa in the year 1551 of the era of king Śaivāhara.”

The author has seen a number of commentaries on the *Nīlkanthi*, in many of these the above verse was missing; it was found only in a few commentaries. It is an instance of how our people are indifferent in the matter of specifying the dates of the compilation of their works. There is absolutely no doubt about this. It authentically becomes evident from the references at other places in the commentary. Visvanātha has written commentaries, consisting of illustrative examples, on several works like the *Suryasiddhānta*. For the main example in them he has adopted Saka 1534 as the year, but has incidentally also, taken Saka years 1530, 1532, 1542 and 1555. In the commentary on 'Pāṣaṣarāṇ', he has adopted Saka 1553 as the year for his example. In the *Kṛṣṇa-vijāta-ka-paddhati*, he has adopted for his example Saka 1508. The birth horoscopes are cast with the help of the *jāta-ka-paddhati*. It would appear that Saka 1508 may have been the date of birth of Visvanātha and he appears to have compiled his works between the Saka years 1534-56. In a line from his commentary on *Gṛahatā-ghava*, (already given on page 131) he calls Gaṇeśa Daivajñya his preceptor, but it is simply a matter of formality. It is like the remark by Dharmarāja, the commentator of the *Mahādevī Sārṅgi*, who in his commentary written in Saka 1557, calls Mahādeva his preceptor, even though the *Mahādevī Sārṅgi* was compiled in Saka 1238.

• Kṛṣṇa śāstrī Gobbole has given in the *Gṛahāṅghava* three verses at the end which state that, in order to ensure agreement with observation, *Viṣṇanātha* has mentioned a correction to it 211 years after it was compiled. This means that the date of *Viṣṇanātha* comes to Saka 1653. But it is quite evident from his family history and his works that the date of *Viṣṇanātha*, the commentator of the *Gṛahāṅghava*, must be in the 16th century and not the 17th. The author has seen several editions of *Viṣṇanātha*'s commentary on *Gṛahāṅghava*, but they do not contain these three verses. *Viṣṇanātha*, referred to in them, must be a different person. *Viṣṇanātha* *Daṇḍi*ya *Saṅgam*śvarkara, the son of *Gopāla* compiled a work entitled *Vratarāja* at *Vārāṇasī* in Saka 1658. The above three verses may have been compiled by this *Viṣṇanātha*.

Visvanātha has written the following commentaries containing examples:—

(1) The *Gaṇadārīha Prakāśikā* Tika on the *Sūrya Siddhānta*. In this, *Viśva-nātha* writes, "I am elucidating the *Sūrya Siddhānta*, the commentary by *Nṛsiṃha* may be consulted for its theory". *Nṛsiṃha* wrote his 'Saurabhāṣya-commentary' in Śaka 1533. From this it is evident that *Viśvanātha* wrote his

Udāharaṇa on the Surya Siddhānta after that date. The number of verses in it is 5000. (2) Siddhāntasīromani\* (3) Karaṇa Kutubhala (4) Makaranda (5) Grahālaghava (6) Pāṭasaraṇi by Gaṇeśa Daivajñya (7) Anantaśudhārasa\* (8) Rāma Vinodakaraṇa\* (9) the Karaṇa work by his brother Viṣṇu\* (10) Keśavi Jātakapaddhati (11) Samāntaniraprakāśika on Tājaka-Nīlkaṇiṇi. This belongs to śaka 1551. The Aufrecht's Catalogue has mentioned the following additional commentaries on :—(12) Somasiddhānta (13) Tīthi Cintāmaṇi (14) Candrama-nāntara (15) Bṛhajjātakā (16) Śrīpatipaddhati (17) Vasiṣṭhasaṃhitā (18) Bṛha-tsaṃhitā.

Viśvanātha has added solved examples in the commentaries and hence those commentaries are very useful for the student. Kṛṣṇa Śāstri Goḍbole has published a Marāṭhi edition of Grahālaghava containing solved examples, which is for the most part, a translation of the Viśvanāthi commentary.

Viśvanātha has not given any theory in his commentary; still the fact that he had a good knowledge of the astronomical science is evident from his works. He compiled all his works at Vātanasi.

### NṚSĪMHA (Birth date 1508)

He was the son of Kṛṣṇa who was the eldest son of Divākara of Golāgrāma (page 154). He was born in Śaka 1508. He was guided in his studies by his uncles Viṣṇu and Mallāri. He wrote a commentary on the Surya Siddhānta entitled Saurabhāṣya in Śaka 1533. It explains the theory and contains 4200 verses. His commentary on the Siddhānta Siromani named Vāsana Vārtika was written in Śaka 1543. It was also called Vāsana-Kalpalaṭā and the number of verses in it is 5500. From both these commentaries it seems that he had a sound knowledge of astronomy. His son Divākara has written that he was very proficient in Mīmāṃsā.

### ŚIVA

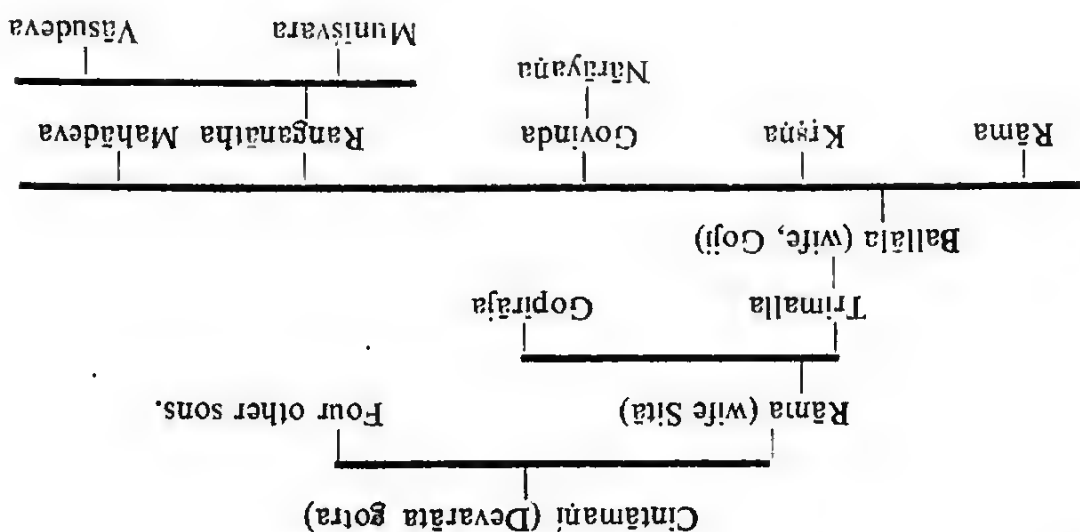
Born in the family described in the author's account of Viṣṇu (P. 154), Śiva was the brother of Nṛsiṃha and son of Kṛṣṇa. His birth year may have been Śaka 1510. Sudhākara states that he had written a commentary on Ananta Śudhārasa. He has compiled a muhūrta work named Muhūrta Cūḍa-maṇi. Divākara, his nephew and disciple, has written in his work Jātakapaddhati, that he was a 'jagadguru' (world teacher).

According to Sudhākara, there was another Śiva, son of Rāma Daivajñya, who wrote a work entitled Janmacintāmaṇi.

### KṚṢṆA

He was born in a well-known family of scholars. The genealogical table below has been prepared from the family history given by the writers born in this family.

\* The author has not seen these four commentaries himself. He has given the names from the Ganaśaṅgī.



## PLACE

Cintāmaṇi, a Yajurvedi Brāhmaṇa, used to reside in Dadhigṛāma, a village on the Bank of Payoṣṇi in vidarbha. The position of this village has been described by Muniśvara at the end of his Marici commentary in the line,

एतावत्पर्यन्तं नरे पश्यन्त्यस्य स्थितिम् ॥

meaning "In the auspicious (Village of) Dadhigṛāma, situated on the bank of Payoṣṇi, in the same latitude as Ellīcūr".

The *Palabha* of Dadhigṛāma, mentioned in commentary on the Keśavi Jātaka written by Nārāyaṇa, son of Govinda, is 4-30, from which the latitude of the place would come to be 21°-15'. This is also the latitude of Ellīcūr. It appears, therefore, that Dadhigṛāma must be a village situated to the east or west of Ellīcūr, in the same latitude.\*

Ballala went to Vārāṇasi to reside there permanently. His descendants, as it appears from their works, continued to reside at Vārāṇasi. However, it appears from Nārāyaṇa's commentary on Keśava's *Jātaka-paddhati* that he compiled it at Dadhigṛāma.

## HISTORY OF ANCESTORS

Kṛṣṇa and Muniśvara have written in their works that Rāma possessed such a wonderful prophetic faculty that the King of Vidarbha always obeyed him. The date of Rāma, as reckoned from those of Kṛṣṇa and Muniśvara appears to be about Saka 1440. When the Bahamaṇi kingdom was split into five parts about 1500 A. D. (Saka 1422), one of the parts was transformed into the Kingdom of Berar (Vidarbha) with Ellīcūr as its capital. As Rāma is said to have been the adviser of the King of Vidarbha, he must have been residing at Ellīcūr. Ballala was a great devotee of Rudra (Śiva). Ranganātha has stated in his commentary on the Śūrya Siddhānta that Rāma, the eldest

\*By the formula tan. lat. = *Palabha* - 12, the given *palabha* 4/30 would indicate 20°34' (not 21°15') as the latitude of the place. (R.V.V.)

son of Ballāla compiled a theory work to explain the 'Anantasudhākara.' This may be the same as the *Sudhārāsa* of Ananta referred to on page 145. This Rāma also was a great devotee of Śiva ; and, according to the Marici commentary, he was alive in Śaka 1557, the date of that commentary.

### KRṢṢA HIMSELF

Kṛṣṇa was the second son of Ballāla. He wrote a commentary work, *Biṣa navānkura*, on Bhāṣkarācārya's 'Biṣagāṇita'. The commentary has also received *Biṣapallava*, 'Kālpalāṭavātara,' as additional names. Kṛṣṇa has suggested in it some new artifices of his own. The commentary has proved to be the best of the ancient commentaries and is recognized as such by learned men. In this commentary, he calls himself a disciple of Viṣṇu who was the disciple of Nṛsiṃha, the nephew of Gaṇeśa, the author of the *Grahaṭāghava*. It is not known if this Viṣṇu was the same as the Viṣṇu of Golāgrāma (page 154). The dates of both of them appear to be almost the same. Kṛṣṇa has written a commentary, consisting mainly of examples, on the Jātakapaddhati of Śrīpati. He has adopted in it Śaka 1478, the birth Śaka of Khāṇkhān, the minister, by way of example in it. There was no possibility of Khāṇkhān to be a minister before Śaka 1500. Ranganātha has referred to both these commentaries by Kṛṣṇa in his commentary on the *Sūryasiddhānta*, and he also writes there that Kṛṣṇa was held in high esteem at the court of Emperor Jehangir. Jehangir ruled from Śaka 1527 to 1549. From this, Kṛṣṇa appears to have compiled, both the commentaries during the period Śaka 1500 to 1530. He has written another work 'Chāḍaka Nirṇaya', which had been published by Sudhākara Divedi. It appears from the commentary, Marici that he had won the affection of Nuruddin, a Muslim officer, and that he was not living in Śaka 1557.

### DESCENDANTS

Nārāyaṇa, son of Govinda, has written a commentary on Keśava's Jātakapaddhati, in which he has adopted Śaka 1509 for the purpose of illustrative examples. There is a work on algebra, named Nārāyaṇīya Biṣa consisting of aphorisms in Arya metre. The author of the *Gaṇaka Tāraṅgiṇī* says that it may have been compiled by Nārāyaṇa. Furthermore, this Nārāyaṇa may be identical with Nārāyaṇa, the guru of Munisvāra.

### RANGANĀTHA

An account of his family has already been given while describing Kṛṣṇa's family. He wrote a commentary, *Gūḍhārtha Prakāśika*, on the *Sūrya Siddhānta*. A detailed description of it has already been given. He has given in the commentary itself, the date of its compilation in the following verse :—

एकं त्रयविंशत्यं १५२५ चक्रमात्रं भूतं चरितव्यं वर्षकद्वयम् ।  
द्वयविंशत्यं चरितव्यं ५२१३० चात्रैव चरितव्यं त्रयविंशत्यम् ॥

*Translation :—*(not necessary)

Ranganātha says that his son Munisvāra, and the commentary *Gūḍhārtha prakāśika*, both appeared 52½ ghatis after sunrise, on Wednesday, the 'Sivāniti' of the bright (or dark) half of Caitra in Śaka 1525 ; and it is written in the same





The sum of all these numbers  $(8+1+3+1+13)$  i.e. 26 increased by 13 and multiplied by 40 would give the year (=1560) of completion of the work.

These verses show that the commentary (first half) was completed on Sunday, the 3rd lunar day of the bright half of Āṣāḍha in Śaka 1557, the nakṣatra being Puṣya and yoga being 'Vyaghāta'. The latter half was completed in Śaka 1560.

Sudhākara says that the Siddhānta-sarvabhāṣya was completed in Śaka 1568, and the author's own commentary on it was completed in Śaka 1572. The Marīci commentary is a voluminous work and the number of verses in it being 25000. It contains a very large collection of quotations from ancient authors. The commentary on Līlāvati contains 7000 verses and has won recognition from scholars. The commentary on the first half of the Sarvabhāṣya contains 8000 verses. It is seen at several places in his works that he was a staunch admirer of Bhāskara's. The length of the year, the number of revolutions of planets and other measures adopted in the Sarvabhāṣya-Siddhānta are the same as in the Śūrya-Siddhānta.

Muniśvara was also known by another name, Viśvarūpa. He writes in his commentary, Marīci, that he obtained knowledge through the favour of Kārtikeya. He states that, Kṛṣṇa's disciple Nārāyaṇa was his guru. Both of them probably belonged to the same family. His works show that he may have obtained the patronage of Emperor Śahajāhan. In his Sarvabhāṣya Siddhānta, he has recorded the year of the Hīrī era and the date and time of the coronation of Emperor Śahajāhan, and also the horoscope of the moment. From this we come to know that Śahajāhan was crowned on Monday, the 4th February, 1628 A. D., the 10th lunar day of Māgha Sukla, of Śaka 1549, (the year 1037 according to Hīrī era) at 3 ghatis after sunrise.

#### DIVĀKARA (Birth śaka 1528)

He was the son of Nṛsiṃha, a scholar from the learned family of Golagrāma (see page 154). He was born in Śaka year 1528. He received all his education from his uncle Śiva. At the age of 19 in Śaka 1547, he compiled a *śāṭaka* work named, *śāṭakamārgapadma*, which is also known as 'Padma-śāṭaka'. In Śaka 1548, he wrote a commentary, named *Praṇḍha-manorama*, on Keśava's *śāṭaka-paddhati*. He similarly compiled in Śaka 1549, a commentary on his own 'śāṭaka' named 'Gaṇitātīva-Cintāmaṇi', with examples.

There is a commentary (with examples) known as Makaranda-vivaraṇa on Makaranda, a work intended to be helpful in Pañcāṅga calculation. His works show that he was proficient in grammar, logic, poetry and literature.

The author has seen the work, Makaranda Vivaraṇa. The remaining account has been given from the information contained in the *Gaṇakāṭaṅgīnī*. His brother Kamalākara received his training from him.

#### THE SIDDHĀNTATĀTVA VIVEKA OF KAMALĀKARA

Siddhānta tāṭva-viveka is a siddhānta work by Kamalākara. Kamalākara's family history has already been given in the account of Viṣṇu (Page 154). His birth date may be about Śaka 1530. The work *Tāṭva-viveka* was compiled at Varānasi in Śaka 1580. It follows the modern *Śūrya Siddhānta* most faithfully. Kamalākara's pride in the *Śūryasiddhānta* had reached such a stage that he felt

that whatever was not found in the *Suryasiddhanta* was false, and even if the same method in the *Suryasiddhanta* were crude, while that in another *siddhanta* more accurate, he would still regard the latter as faulty. Thus, for instance, the correction of *udayāntara* was discovered by Bhāskaraçārya, but Kamalākara regarded it as erroneous since it was not given in the *Sūrya Siddhanta*. He likewise attempted to prove that the correct method of finding the length of the circumference of a circle was the one given in the *Sūrya Siddhanta*, viz. to multiply the square of the diameter by 10 and to extract the square root of the product, even though the method given by Bhāskaraçārya is really more accurate. It is needless to say that he has adopted all things like the numbers of revolutions and other elements, from the *Sūrya Siddhanta* and has even borrowed some verses exactly word by word. This work contains 13 chapters on the following subjects :—mean places, true places, three problems, discs, shadow, elevation of moon's cusps, rising and setting, possibility of eclipses, lunar eclipse, conjunction of planets with stars, Mahāpātā and problems. All these subjects comprise 3024 verses in different meters. They are interspersed with prose passages and he has added a chapter named "Sesa vāsana" in which he has given the theory of those subjects in the body of the book which was not given at the proper place. This work has been recently published by Sudhākara Divedi at Varānasi Series.

Although the great drawback of Kamalākara has been pointed out above, his works contain many new things not to be found in the earlier works. They are :—He has stated that the place of the pole star does not remain fixed owing to the precession of the equinoxes. Similarly, that the pole star which we see at present is not situated exactly at the pole (of the equator) and its place is found to have changed when observed early at night and late in the latter part of the night. He says that it is the view of the Greeks that the major part of the earth's surface is under water and only a minor part outside it. The distance, in degrees, of a place from any meridian, in the east-west direction, which is now known as longitude, was termed by him as *Tulāṃśa* and he has given a list of latitudes and longitudes of 20 cities as below on the assumption that Khālādātta, a city on the equator, was on the Prime Meridian :—

Place	Latitude	<i>Tulāṃśa</i>	Place	Latitude	<i>Tulāṃśa</i>
Kabul	34 40	104 0	Ahmedabad	23 0	108 20
Khambayat	22 20	109 20	Burhanpur	21 0	111 0
Ujjayini	22 1	112 0	Lahore	31 50	109 20
Indraprastha	28 13	114 18	Argalapur	26 35	115 0
Somanath	22 35	106 0	Vijapur	17 20	118 0
Varanasi	26 55	117 20	Golkonda	18 4	114 19
Lucknow	26 30	114 13	Ajmer	26 5	111 5
Devagiri	20 30	111 0	Multan	29 40	107 35
Kanauj	26 35	115 0	Mandava	27 0	121 0
Kashmir	35 0	108 0	Samarikand	39 40	99 0

He has described in detail, the method of taking observations by the quadrant "instrument" and "eclipses". He has also mentioned that at the time of the solar eclipse, an observer on the moon's disc will be able to see the earth engulfed in the shadow. The remarks that the Greeks had observed the transit of Venus across the Sun's disc. The causes of the clouds, hailstorm, earthquake, and the falling of meteors, have been explained by him. They are not wholly true, they are at least not based on superstition and in the truth. His works show some new methods related to the study on arithmetic, geometry, mensuration and trigonometry. Other siddhantas, assume 3438 units as the radius of the earth, and give values of the sines of angles at intervals of  $3\frac{1}{2}^\circ$ . He has as-sumed 60 units as the value for the radius of the earth and given values for the sines of each degree, which are very convenient. A table has been given for finding the right ascension of a planet from its longitude. Other Siddhantas give neither this table nor the method; these are given only in Kero-pant's work. In short, his work has many features. It is, however, very difficult to find out how many of them he can claim as his own. It is a matter of regret that original ideas appearing in his work were not further developed.

That his brother Divākara, was his guru, has already been mentioned above while citing the verses from his work. Kamalākara was bitterly opposed to Munisvara, the author of the *Sarvabhāva-Siddhanta*. They were contemporaries. One wonders whether it was due to jealousy that he began to hate Munisvara and consequently also Bhāskara's works. Ranganātha, Kamalākara's youngest brother, wrote *Bhāṅgībhāṅgī*, in order to refute Munisvara's 'Bhāṅgī', the method of finding the true places of planets. Munisvara, in his turn, made a counter attack (*Gaṇakatarāṅgī* page 92.)

### RANGANĀTHA

He was born in the famous family of scholars at Golāgrāma (see generalo-gical table on page 154). His birth year may be about 1534. He wrote the '*Mūlabhāṣā*', a commentary on the *Siddhanta śiromaṇi*. Sudhākara writes that he had compiled an independent work, named *Siddhanta Cūḍamāṇi*. It has 12 chapters and contains 400 verses. It follows the *Suryasiddhanta*. Ranganātha has mentioned the date of its compilation as follows:—

मानी कालिष ४ इत्युत्तराय चोत्तरायैतौ तौ  
 वर्ष ५ इति २ इत्युत्तरायैतौ ३ यत्प्राप ॥  
 पक्षः उत्तरायैतः शक्ती विवर्तते १५०२ युक्ता ।

Translation:—

Calculation based on the above data shows that this work was completed on Friday (6), the full moon (15) day of Pausa\* (10), Śaka 1565\*\*, the nakṣatra and the yoga on that day being Ardra (6) and Brahma (25) respectively.

\* Sudhākara has arrived at Śaka 1562 as the date referred to in this verse; but it is an error due to oversight. The third nakṣatra that he mentions was not possible on the fullmoon day of Pausa in that Śaka year. The nakṣatra happens to be the sixth; and taking that into account, the sum would not come to 1562.

\*\* The month seems to have been puzzled out by trial and error as the original verse does not contain any clue to its name or number. Pt. Sudhākara also remarks that number 10 has to be presumed here as the number of the month because it fits the case completely. (R. V. V)

## SIDDHANTARAJA

By

NITYĀNANDA (Śaka 1561)

## BRIEF ACCOUNT

Nityānanda compiled the work 'Sarva Siddhāntarāja' in the year Vikram Samvat 1696 i.e. Śaka 1561. He was a resident of *Indrapuri* near Kurukṣetra. His gotra was Mudgala, he belonged to the Gauda clan and was brought up in the Duṣṇahatī tradition of teaching. According to Sudhākara, Duṣṇahatī was his traditional native place. The names of his ancestors, from his father upwards, were Devadatta, Nārāyaṇa, Lakṣmaṇa and Icchā respectively.

*Description of works. Their Special Features*

The work 'Siddhāntarāja', is divided into two parts—*Gaṇitādhyāya* and *Golādhyāya*. The first part contains 9 chapters and deals with the following subjects: *Mīmāṃsā* (Rational), mean places, true places, three problems, lunar eclipse, solar eclipse, elevation of moon's cusps, conjunction of planets with stars and shadow. The second part, *Golādhyāya*, contains chapters on the universe, the celestial sphere and instruments. The special feature of this work, which distinguishes it from all other Siddhānta works described so far, is that it follows the SĀYANA system. He has fully discussed in the first chapter on 'Mīmāṃsā' (Rational) how the *Sāyana* system is the supreme system and how it is recognized as such by Gods and Rṣis. The numbers of revolutions and other elements of planets etc., are as follows:—

Kalpa 4,32,00,00,000 years.

The revolutions etc. in this period are:—

Sun	432,000,000	Saturn	146835981
Sun's Apogee	171945	Savana days	1577847748101
Moon	57750968965	Solar months	51840000000
Moon's apogee	488327103	Intercalary months	15909668965
Mars	2296968639	Lunar months	53430968965
Mercury	17939534114	Lunar days	1602929068950
Jupiter	364356698	Suppressed tithis	25081320849
Venus	7022180538		

Number of divine years spent over creation from the beginning of Kalpa.....90410.

Number of solar days in a year 365.24253428

=365 days—14-33-7.40448

the tropical year =365 days—14-31-53.42 (By accurate modern methods).

It can be easily noted that there is considerable difference between the above figures and those given in any of the Siddhāntas described before. The number of days in a Kalpa and the consequent length of the year deduced from it are less than those of others, and the numbers showing revolutions

are greater than theirs'. The number in the case of Venus is smaller, which appears to be due to some error.

The corrections to be applied to planets have been mentioned in the following verses :—

सूक्ष्मादिना गतसमा वयुगानामा ४ (?) ६४० स्तरेण गतेष्वन दृष्टेभ्योऽप्युक्तं यः

भासः स एव दिक्पदद्विजिह्व ॥

शीघ्रादिभ्योऽप्युक्तं यः ४७३० विजिह्व २१० स्तरेभ्यो ४८० दृष्टेः ६२०

पञ्चानि ६४०. ४६० क्वाभ्यर्द्धः १०१० क्वापि ॥

यदिद्वै १३१० द्वाभ्यामेव दिष्टेन नव क्वापि विजिह्व

यदिद्वैयुक्तेषु युक्तस्य नवद्विजिह्वोक्त्यपि ॥

सूक्ष्मे पञ्च विजिह्वः सदा स्त ॥

The author remarks at the very beginning,—

दृष्टे रीमक्षिह्वेति सौरं च ब्रह्मगुप्तक ॥ पञ्च स्तरेण गतेषु भासो विह्वेति

सिद्धं स्तरे ॥ १४ ॥

"After studying the Romaka, Saura, and Brahma Siddhantas, and after calculating places of planets, the writer compiled this accurate Siddhanta."

It is not known which Romaka Siddhanta is meant here. The differences in the measures will show that it can neither be the *Romaka Siddhanta* of the *Pāñcasiddhāntikā* group nor that of *Ptolemy*. The *Samrat-Siddhanta* (Saka 1561) also refers to Romaka Siddhanta. The author has no means at present to ascertain what Siddhanta it was or whether it was the same as the one seen by Nityānanda. The author of the work seems to have taken observations himself. There might have been Muslim astronomers at the Delhi Court in his time, and they might have had possessed some works on Muslim astronomy in their possession. A reference to some such works occurs in the *Siddhāntasamrat*. Nityānanda might have seen those works also.

The author happened to see a copy of this work with the late Rao Sahab Viśwanāth Narāyaṇ Mandlik. The copy had been made from a work belonging to a learned scholar at *Jalpur*. It appears that the Siddhanta is well known in those parts. It is not known, however, if the work was ever made use of in the actual calculation of almanacs.

### KRŚNA, Saka 1575

There is a karana work entitled *Karaṇa Kaustubha*, written in Saka 1575. It was compiled by Kṛṣṇa, an astronomer of Kāśyapagotra and a son of one Mahadeo. It has not been mentioned what Siddhanta it follows. But the motions of planets and the epochal positions agree with those calculated from the *Graha Kautuka* and the *Graha Lāghava*, with slight modifications. The author has made a salutation to Kṛṣṇa, the author of *Graha Kautuka*. He says in the beginning,



the son of Mallaya of Kaundinya gotra. No mention has been made of the date of the work or that of its author. There is a commentary on it written about Saka 1634. (This Saka has been taken for an example in it). The commentator has not disclosed his name; but his place of residence, according to the commentary, was *Bankapur*. The *palabha* of Bankapur has been mentioned as 3-18 (hence the latitude would be about  $15^{\circ} 25'$ ), and the longitude as about 13 yojanas ( $1^{\circ}$ ) west of Kartika mountains. From this, the place appears to be situated in the *Dharwar* district. This fact and the writer's name would lead one to infer that this work had been in use in *Karnataka*, and the date of its compilation was earlier than Saka 1600; it may have been even more ancient. It contains a verse from the *Grahalaghava*. It is not known whether the author of the *Grahalaghava* has taken it from this work or the author of this work has borrowed it from the *Grahalaghava*.

The length of the year and the revolutions of planets have been taken from the modern *Surya Siddhanta*, and a correction has been mentioned for them. The correction for Mercury, as mentioned by Makaranda, is negative, while that given in this work is positive. Similarly the Makaranda does not at all mention any correction for Mars, while this work gives plus  $2\frac{1}{2}$  revolutions; all other corrections are the same as those given in Makaranda.

From the list of corrections, this work does not appear to be older than Saka 1400. The *Aufrecht Catalogue* mentions another work *Grahana Mukura* by Viddana.

### PHATTESHAHA PRAKASA

By

JATADHARA, Saka 1626.

This is a Karana work. The epochal year of this work is Saka 1626 which was the 48th year of the reign of king Phatte Saha of the Candra dynasty at Badri Kedar, near Srinagar. Its author is JATADHARA by name. His father's name was Vanamali, that of his grand father was Durgamistra and that of his great-grand-father, Uddhava. His gotra was Garga. Jaiadhara was a resident of Sarhind.

### DADABHATA

The *Kirandalli*, a commentary on the *Surya Siddhanta*, was written by Dadabhata or Dadabhai, a Citpavan Brahmana, in Saka 1641. His father's name was Madhava and surname Gaohkar. A reference to this commentary has already been made in the course of the authors comments on the *Surya Siddhanta*.

### ACCOUNT OF FAMILY

According to *Aufrecht Catalogue* Madhava had written a work entitled *Samudrika Cintamani*. Narayana, Dadabhata's son, has written in the colophon of his *Tajakassudhanidhi*, that MADHAVA was "in the service of Sri Isa in the Pashupatinagar", from which he appears to have been staying at

Varānasi. Madhava had two sons, of whom Dadabhata was the elder. Dadabhata had two sons, of whom Nārāyaṇa was the younger. Nārāyaṇa compiled the following works:—

(1) Horāśtrasudhānidhi (2) Nārājātakaavyākhyā (3) A ' Prāśna ' work entitled Gaṇākāpriya (4) A ' Sakuna ' work, named Svārasāgara (5) Tājaka-sudhānidhi. The date of all these works appears to be about Saka 1660.

### JAYASIMHA

Jayasimha was a unique personality so far as the science of Indian astronomy is concerned. Copernicus was born in Europe about the same time as Kṛṣṇa Daivajña and Gaṇeśa Daivajña, the two research-minded astronomers, were flourishing in our country, and the condition of astronomy both here and abroad could be said to have been similar till that age. But a great transformation took place in the condition of astronomy in Europe from Copernicus onwards. One may safely say that the science has now attained the acme of knowledge so far as the motions and positions of planets are concerned. It is true that the discovery of telescope and the needs of navigation were particularly responsible for this remarkable progress; still, it must be admitted that unlike Europe, our country failed to produce a galaxy of talented and diligent scholars capable of bringing about a similar advance of knowledge. It is found, only JAYASIMHA in our country could be named as the solitary exception, comparable with the European scholars of his time.

Jayasimha was a king in Rajputana. He ascended the throne at Ambher in Vikram Samvat 1750 (Saka 1615, i.e. 1693 A.D.). Later on, he built the present city of Jaipur and made it his capital. In his work, Siddhāntasamrat, he has been styled "Matsya deśādhipati". He set himself the task of compiling a work, after taking observations with newly built instruments, set up in newly built observatories, because no existing Hindu, Muslim, or European works could give results agreeing with observation; and accordingly he accomplished his task with success. He established observatories at Jaipur, Indraprastha (Delhi), Ujjayini, Varānasi and Mathura. He got built very big, immovable instruments, made of mortar and stone, huge in size and very useful for observation, because, he found that metallic instruments are very small in size and wear out easily. Of these, the Japirakāśa, Yantrasamrat, Bhūtiyānta, Vitisāṣṭhāṃśa etc. were newly devised by him; and after engaging a staff of competent astronomers as observers for seven or eight years, he compiled a work entitled viz. 'Muhammad' in Arabic and Siddhānta Samrat in Sanskrit, on the basis of the records of observations taken. At that time, MUHAMMAD SAH was the Emperor of Delhi and the first work was named after him. It appears that it was also called 'Mijasti'. This work belongs to the year 1141 of Hijri era (i.e. Saka 1650). He got the Siddhāntasamrat compiled by a scholar, JAGANNĀTHA, about Saka 1653 (i.e. 1731 A.D.). It is mainly a translation of the work, Mijasti. It consists of 13 chapters, containing 141 articles and a study of 196 propositions (Kāśētras). The work records the observations taken in the year 1650-51-52; and the elements such as planetary motions have been determined, after comparing his own observations with those of ULUGH BEG and other ancient observers.

\*The latitude of Indraprastha has been given as 28°39' which tallies with the present day estimate.

The Siddhāntasamrat could not be obtained in its complete form in this province. The Anandāśrama possesses a copy of the book prepared from the incomplete work in the possession of the Rājajyotiṣī (palace Astrologer) of Kolhapur. It contains two chapters in the beginning which describe, by way of introduction, the earth and the celestial sphere. The first chapter contains 14 articles and a study of 16 propositions (Kṣētras), and the second, 13 articles with 25 theorems. The book contains, in addition, a study of instruments and problems in geometry and trigonometry, three problems and mean & true places. The "spāṣṭādhyāya" is incomplete, and this portion contains a study of 67 propositions. All these together make about 5500 verses. From this it appears that the complete work may have consisted of about 10000 verses. Sudhākara says that according to a legend, the number was about 50000; but it is an impossibility. Moreover, Sudhākara too has not seen the entire work.

If a description of the observatories built by Jayasimha, and of the observations taken, and the items of original information gleaned from these, be attempted, it would take a small volume. It is enough to state here, however, that *Jayasimha ensured a higher degree of accuracy in the calculation of planetary positions and motions than that achieved in Europe in those days.* This reflects great credit on him as well as this country. The length of the year adopted in this work is tropical and the rate of annual precession about 51".4. The planetary places obtained from the work appear to be sayana. We are instructed to take the nirayana places obtained by applying the ayanamśa-correction. The numbers of revolutions and other elements also appear to have been given as in the Śūrya Siddhānta along with corrections to be applied to them.

It is not that the work in Arabic might have been entirely compiled by Jayasimha himself. He had many scholars under his patronage and he might have got it compiled by them. The Siddhānta Samrat which is for the most part a translation of the Arabic work was compiled by Jaganmūṭha. Nevertheless, Jayasimha was himself a good observer, a mathematician and an astronomer. The works mention the fact that some of the subjects were explained by him in quite a new way; and the idea of first taking observations and then compiling a work that would give results in conformity with observations was first originated by him. He had engaged competent artisans and scholars knowing one or both the languages, Sanskrit and Arabic. He had sent astronomers even to foreign lands to take observations. It is obvious that the observation work has to be carried on at several places and by several persons working in co-operation.

The Siddhānta Samrat describes the instruments newly designed by Jayasimha. A description of his observatories and instruments has been given later on in the chapter on 'Observations'.

The Siddhānta Samrat refers not only to ancient works in Sanskrit but to a work compiled by ULUGH BEG, grandson of Tamerlane in the Hijri year 841 (i.e. Saka 1359). It refers also to a work compiled by *Boosanaśar*, which seems to have been compiled 619 years before that of Jayasimha. This figure may be indicating years of Hijri era. It refers to the *Romakasiddhānta* and to the Yavana (Arab) astronomers, *Batālmajūna* and *Awarakhas*.

Jaganmātha translated in Śaka 1641, 15 books of Euclid's geometry in to Sanskrit, under orders of Jayasimha. It is called 'Rekha-gaṇita'. It is well known in Jaipur province. There is a copy of this book in the Anandaśrama library (Book No. 3693), Poona. It does not mention Euclid's name. It is said to have been prepared with the help of works compiled by Rsis; there is, however, no doubt that it was compiled with the help of Euclid's work. It may have been compiled from some Arabic work which did not make any mention of the original writer, or else which contained some words suggestive of the "apuruseya" (divine) nature of the work and a similar remark might have found its way into the Sanskrit work also.

Sudhākara writes that Jayasimha offered some villages to Jaganmātha by way of reward and they are still in the possession of his descendants.

Jayasimha got another work entitled 'Kaṭa', compiled by 'Navanasa-khopadhyaya'. It is an independent work different from Euclid though compiled on the same lines. It contains three chapters which respectively consist of 22, 23 (or 22) and 14, i.e. 58 or 59 theorems in all. The first two chapters deal with theorems about circles on spheres. This book was originally written by 'Stavasisayisa' in the Greek language. It was then translated into Arabic under the orders of Abul Accas AHMED. There is a commentary on it compiled by NASIR. It has been stated in the work that it was translated from Arabic into Sanskrit.

The enterprises of Jayasimha were not continued further. No one makes any use of his observatories and now they are mostly in a dilapidated condition. Jayasimha's work, Siddhanta Samrat also does not appear to have come into use; nor have almanacs been rectified therefrom. The length of the year is still the same as before. And the same works which guided the almanac-makers before the time of Jayasimha continue to hold the field to this day. The fact that Jayasimha's works were not used even in Raj-putana, is really very deplorable and thought-provoking.

### VAISNAVA KARANA

By

SANKARA, Śaka 1688

Sankara belonged to Vasisṭha gotra and was a resident of the region around Ratatāka hill (near Dwaraka). The names of his ancestors, from his father upwards were Śuka, Dhaneśvara, Rāma and Harihara. He compiled a Kara-na work entitled *Vaiṣṇavakaraṇa* in Śaka 1688. Although he has observed in the beginning that he proposed to compile it according to Viṣṇugupta's views, he has, in reality, followed the Bhāskara's views. He perhaps meant to name Brahmagupta, son of Jisṇu, in place of Viṣṇugupta. This work adopts a Zero ayanamśa for the Śaka year 445. The work contains about 300 verses. It is claimed that this Karaṇa work would give planets places agreeing with observation. But it contains nothing more than earlier works, Gaṇakataranginī, pp. 110-111.

## GRAHAGANITA CINTAMANI

By

MANIRAMA, Saka 1696

## BRIEF ACCOUNT

Manirama was a Yajurvedi Brahmana belonging to Bharadwaja gotra. The names of his three ancestors, starting from his father, were Lalama, Devadasa, and Lladhara. His guru was one Vatsaraja of Kasypa gotra. All these names suggest that Manirama was a Gujarati. The verses describing his family history show that his name may have been simply Rama.

## Outline of Work

The Grahaganita Cintamani has given epochal positions for the morning of Sunday, the first lunar day of Caitra Sukla, of Saka 1696 (i.e. 13th March, 1774 A.D.). They are:—

Sun	Moon	Moon's apogee	Moon's node
11	11	0	15
15	4	29	36
1	6	21	55
Mars	Mercury's (mean) elongation	Jupiter	Venus's (mean) elongation
10	1	11	4
13	17	29	23
4	5	57	54
51	12	0	54
12	12	0	12

Sun	Moon	Moon's apogee	Moon's node	Mars
+0	+0	+1	-0	-0
0	0	36	17	6
24	51	8	22	37
Mercury's (Mean) elongation	Jupiter	Venus's (Mean) elongation	Saturn	
+1	+0	-2	-0	
14	20	56	9	
31	33	34	17	

Difference from those of Grahaghava (Gr. I.-23 cycles; aharagana=388)

This work has employed the same device as *Grahaghava* in order that *aharṅga* may not exceed a certain number. In other words it has assumed a cycle of 11 years and the explemet of the motion during this cycle is termed '*Dhruva*'. These '*Dhruva*' figures are more accurate than those of *Grahalaṅghava*. The author is a follower of the *Sūrya Siddhanta*; still, he has not adopted the positions as they are actually obtainable from the *Sūrya Siddhanta*. Again, though the method of procedure adopted in the work is almost the same as that of *Grahalaṅghava*, the author has not relied upon that work too far for the places of planets. From this and from his remark in the conclusion, viz. "I have compiled this work, after myself taking observations, according to the methods of observation described by learned men. Scholars may test their accuracy by means of instruments," it appears that the writer has obtained the planets' places at the epoch, after actually taking observations for himself.

He has mentioned a correction due to difference in longitude (*rekṣāntar*) to mean places of planets. Similarly, he has mentioned the corrections of '*bhujāntar*' and '*cara*' for all planets. The *ayanāmpas* have been given according to the *Sūrya Siddhanta*. The method of calculating true places of planets is like that of *Grahalaṅghava*. However, the figures for the heliocentric and geocentric positions are somewhat different.

The work contains 12 chapters on the following subjects:—mean places, true places of the sun and the moon, true places of planets, calculation of the ascendant etc., lunar eclipse, solar eclipse, graphs, re-appearance of the moon, construction of the '*nalikā*' instrument, elevation of moon's cusps, heliacal rising and setting and *Mahāpāt*. The number of verses in it are respectively 19, 11, 14, 7, 5, 3, 7, 3, 26, 4, 6, 15, i.e. 120 in all. There is a copy of this work in the Anandaśrama (library), Poona. (Book No. 3103).

#### *No Setback to Grahalaṅghava*

A number of attempts appear to have been made to compile a work similar to the *Grahalaṅghava*. The author has not found among these any work as good as this one. Of course the author of this work cannot be credited with capacity for original work like that of the *Grahalaṅghava*; still, it is only fair to observe that he has given planetary positions agreeing with observed results; and, judged only as a *karana grantha*, this work is by no means inferior to the *Grahalaṅghava*. Nevertheless, *Grahalaṅghava* has been in extensive use all over the country and in spite of its great antiquity it is not found inconvenient for calculation. Moreover, many astronomers have prepared tables in order to simplify all its calculation work. For all these reasons the *Grahalaṅghava* has not been beaten as yet by any of its successors.

#### BRAHMA SIDDHANTASARA, Saka 1703

This is a work belonging to Brahmapakṣa. It contains 12 chapters. It has adopted Saka 1703 as its epochal year. The first chapter comprising 124 verses, is a synopsis of the chapter on mean places from the *Siddhanta Siromani*. Then follows the main part of the original work. It follows the method of computing planets' places from *aharṅga*. Some of its methods are similar to those of the *Grahalaṅghava*. The author of the work, named *Bṛuḷa*, was the son of *Narāyaṇa* and a devotee of goddess *Dēvi*; he was a Brahmapakṣa belonging to *Gargya goṭra*, and used to reside at *Dadhici*, a place at of the mouth of the *Narmada*.





## WORKS

All his works on astronomy have been compiled with a view to simplifying planetary calculations to be made according to the *Grahalāghava*. They consist mostly of tables, and are very useful for study, because solved examples have been given in them. The works are:—(1) *Graha Vidyāna Sārāṇi*: This contains tables useful for calculating mean and true places of planets. The Saka years used in the examples are 1734, 39, and 44. (2) *Māsa-praveśa-sārāṇi*: how to compute the true daily position of the sun, for the sake of finding the moments of the commencement of a new day, a new month, and a new year of life, according to Tājaka system. The solved example has adopted 1744 as the Saka year, 4 as the palabhā, and 28 W. Yojana as the longitude; (3) *Lagna Sārāṇi*: tables for finding ascendants. (4) *Krāntisārāṇi*: tables for finding the declination. Saka year 1753 has been selected for the example. (5) *Candodayāṅkajālā*: Saka year 1757 adopted in the example (6) *Drikkarṇa Sārāṇi*: Saka year 1758 taken for the example. (7) *Grahaṅkajālā*: The example has adopted Saka 1755—1761 as the years (8) *A commentary* on the *Paṭasārāṇi* (Tables for the calculation of Mahapāta) by Gaṇeśa Daivajña, Saka 1444. The example adopts Saka 1761 as the year. (9) *Xanira Cintāmaṇi-Tika*: This is a commentary on the work on instruments by Cakradhara. Dīnakara was an ingenious astronomer and his works show that he had a good knowledge of observations.

## GRAHALĀGHAVA METHODS SIMPLIFIED

A number of astronomers possess tables like those prepared by Dīnakara that are useful in making any calculation by the *Grahalāghava* methods and especially for finding the mean and true places of planets. The calculation which normally takes 2 to 2½ hours if done according to the method described in the *Grahalāghava* verses, can be finished in nearly half an hour with the aid of such tables. YĀMAN KṚṢṆA JOŚI, Kannaḍkar, published in Saka 1803 a work, entitled, "Bihat-Paṭhaṅg-Sādhanaodāharaṇa" which contains such tables. The printed version of 'Kēśavi (collected works of Kēśava, the father of Gaṇeśa Daivajña) contain similar tables. Nevertheless astronomers are found as do not have any idea of such devices and short cuts and are consequently required to follow the laborious method of calculation.

## YAJÑEŚVARA ALIAS BABA JOŚI RODE

## BRIEF ACCOUNT

His gotra was Sāṇḍilya, his father's name was Sadaśiva and that of his grand father, Rāma. He was the grandson (daughter's son) of Cintāmaṇi Dikṣit of Satara. When British rule was established in Mahārāṣṭra, a Sanskrit College was founded in Poona, and Yajñeśwara was a teacher of astronomy there up to September 1838 (Saka 1760). From what date he was there, is not known. The chief Paṇḍit and astronomer, Subājī Bāpu, of the Sanskrit School at Sihore, Mr. Chaplain, Commissioner of Southern Division, founded the Poona Sanskrit College in 1821 A.D. Afterwards the College underwent such complete transformations in 1851 A.D. that it may as well be regarded to have ceased to exist. (See Report of the Board of Education for 1840, 41, 51 & 52.)

in Malwa, had compiled a small work entitled *Siddhanta Sircamāṇi Prākāśa* in which he presented a comparative study of the mythological views about astronomy, those of the Sanskrit astronomical siddhanta works, and those of Copernicus. R.B. Godbole, author of the *Modern History of India* (Mumbai) writes that Yajñeśwara had compiled the work, "youth-turāṇa-vicchedha Mardan" in refutation of the work of Subāji Bapu while Major Candy has observed that Yajñeśwara was very intelligent and learned, but a very bigoted champion of the mythological doctrine. But there is still another work 'Avirodhaprakāśa' by Nīkāṇṭha, in which it has been shown that there is no contradiction between the teaching of the Purāṇas and those of the science of astronomy. Wilkinson, the Political Agent of Sihore, had a sound knowledge of Indian astronomy. He had got *Siddhanta Sircamāṇi*, printed at Calcutta in 1841 A.D. (Saka 1763). It was on his advice that Subāji Bapu compiled another work "Avirodhaprakāśa viveka" (Saka 1759) in order to refute the arguments advanced in "Avirodhaprakāśa", and sent it to Bābā Jośi at Poona, and Bābā Jośi endorsed the views of the author, as can be seen from the relevant correspondence published in the original by the author of the *Guṇakatarangīnī*.

## WORKS

The following are the works by Yajñeśwara:—His commentary, *Yantarāja Vāsana*, on the work, *Yantarāja*, belongs to Saka 1764. He has also written *Anubhāvika*, a commentary on *Colānand* by *Cintāmaṇi Dikṣit*. The commentary, *Maṇikānti*, on *Laghu Cintāmaṇi*, compiled by some Yajñeśwara may probably be the work of this very author. These works show that Yajñeśwara had a sound knowledge of *Siddhanta* works. He has referred to his work entitled, *Prasnottarimālikā* in his commentary on *Colānand*.

## NĪSĪMHA, alias BĀPUDEVA, Birth Saka 1743

## Brief Account

Bāpudeva was one of those learned men who lived after the establishment of the British rule in India and who were proficient both in the Indian and Western systems of astronomy and mathematics. He was a *Rigvedi Cīpāvan* Brahmana, originally a resident of *Tonke*, on the bank of *Godāvari* in *Ahmed-nagar* district. He was born on the 6th lunar day of the bright half of *Kārtika* in Saka 1743 (i.e. 1st November, 1821). His father's name was *Sitārām* and mother's name *Satyabhāma*. He received his elementary education in a *Maraṭhī* School at *Nagpur*, and in the same city he studied *Bhāskara's Lilāvati* and *Biṣagāṇita*, under the guidance of *Ḍhundhūrāja*, a *Kānyakubja Brahmana* scholar. In Saka 1760, L. Wilkinson, the Political Agent at Sihore, was impressed by Bāpudeva's proficiency in Mathematics and took him to the Sanskrit College (Pāṭhśālā) at Sihore for further study. Here he studied Geometry and other branches of mathematics under the care of *Sewa Rām*. Afterwards, on Wilkinson's recommendation, he was appointed a teacher of Geometry in the Sanskrit College at Vārāṇasi in Saka 1763 (i.e. 1841 A.D.) From that

\* *Sivalal Pāṭhak* of Vārāṇasi had compiled a work entitled *Siddhanta Manjuzā*, which was meant to refute the arguments of the *Avirodhaprakāśa*. Similarly, *Bhāskara*, a disciple of *Śivakāya* younger brother had written a work "Dvya-mukha-capeṭika". Both these (works) had been compiled before Saka 1759.

day he lived at Vārānasi till his death. He became the Head Teacher of mathematics in the same College. He retired from service in Saka 1811. Afterwards, he died in the month of Vaiśākha in Saka 1812, at the age of 69. A number of students received their training under his supervision. He became an Honorary member of the Royal Asiatic Society of Great Britain and Ireland in 1864 A.D. and that of the Asiatic Society of Bengal in 1868 A.D. In 1869, he was made Fellow of the Calcutta University. He was also a Fellow of the Allahabad University. In 1878, he received the title of C.I.E., and in 1887 that of Mahamahopādhyāya from the British Government on the occasion of the Golden Jubilee of the Queen Empress. The ruler of Jammu once awarded him a cash prize of Rs. 1,000 - for having correctly predicted a lunar eclipse.

The works compiled by him were:—(1) First chapter of Geometry (2) Part of a work on Trigonometry (3) The controversy about the Sāyana-system (4) A brief account of the teachings of ancient astronomers (5) Eighteen questions on strange subjects with their answers. (6) *Tattvavivēka parikṣā* (7) A description of the instruments at Mān Mandir. (8) *Arithmetica*. All these works, both small and large are written in Sanskrit and all of them have been printed. In addition to these he wrote (i) 20 verses to explain the theory of Calculus, (ii) some formulae of spherical trigonometry (iii) useful notes on the study of siddhānta works (iv) *The Chedyaka*, useful for Yantraśāstra, and (v) the *Laghu-Saṅkhu-chiṇṇa-kṣetra-guṇa*. These have not been printed. His Hindi works on Arithmetic, Algebra and Astrology from Siddhāntasīromani by L. Wilkinson, and he himself translated the *Sūrya Siddhānta*. Both these works were prepared under the supervision of Archdeacon Pratt and printed in 1861-62. He also published with critical notes the *Gaṇita* and *Gola*, parts of Bhāskara's Siddhānta Sīromani, in Saka 1788 and the work *Līlāvati* in Saka 1805.\*

Every year Saka 1797 to 1812, he used to publish an almanac with the help of the *Nautical Almanac*. A description of the Almanac will appear further in the course of our study of Pañcāṅga. He did not, however, compile any work on the method of the computing the Pañcāṅga.

#### NILĀMBAR ŚARMA, Saka 1745.

He was a Maithilī Brāhmaṇa, residing at Pātālīputra (Patna), four miles from the confluence of the Ganges and the Gaṇḍakī. His father's name was Sambhu Nāth. He studied under the care of his elder brother, Jeevanāth, and later on for some days in the Vārānasi Sanskrit College. He was the Head astronomer at the court of Śiva, King of Alwar. He died at Vārānasi in Saka 1805.

He compiled a work 'Gola Prakāśa' in Sanskrit in the western style. Bāpūdeva printed it at Vārānasi in Saka 1793. It contains five chapters. The following subjects are dealt with in it:—The conception of sines, the theory of (plane) trigonometry and spherical geometry, and the theory of spherical

\*This account is based mainly on the *Ganakaśāstrī*.

trigonometry and problems. This work is very useful for those who do not understand English. He has written a commentary on some sections of Bhāskara's works. His elder brother Jeevanāth, wrote a commentary on Bhāskara's Bijagaita and astrological works like Bhāva Prakāśa.

VINĀYAK alias KERO LAKṢMAṆ CHHATRE, Birth Śaka 1746.

#### Brief Account.

Keropant Nānā was one of the renowned scholars who were proficient in Western learning and who flourished after the British rule became established in Mahārāṣṭra. He was particularly proficient in mathematics, astronomy and nature study. There is a coastal village, named Nāgaon, in Aśtāgar Prant, about 26 miles to the south of Bombay. He was born there in May 1824. He was a Rīgvedī Cīṭpāvan Brāhmaṇa, belonging to the Kāśyap gotra. He completed his studies of the English language and through that medium, the study of Western sciences at the Elphinstone Institute of Bombay. He was a pet student of Prof. Aṛliḅar.

In the year 1840 A.D. an Observatory was built at Colaba, Bombay, to observe the celestial phenomena and to test the effects of magnetic attractions. When it was inaugurated by Prof. Aṛliḅar, he appointed Keropant as an Assistant there. Later, on 7th June, 1851, the Poona Sanskrit College was converted into the Poona College; and after some months, Keropant was appointed Assistant Professor to teach mathematics and natural Sciences to the Marāṭhī section and the Normal School. He used to teach these subjects in the College through Marāṭhī as well as English. Later on, the Normal School section was separated from the College, and he worked as a teacher, and later on, he worked for some years more as Superintendent of the School. The Institution was also known in those days as Vernacular College. (It is at present known as the Training College). In those days he used to lecture also in the Engineering College on the subject of Natural Science. Some time during this period he was the Head Master of the English School at Ahmed-nagar. In 1865, he was appointed a Professor of Mathematics and Natural Science at the Poona College, where he used to teach these subjects through English. The College, later on came to be known as the Deccan College. He retired from service in 1879 A.D. He was, at that time, drawing Rs. 1,000 per mensem and he received a pension of Rs. 5,000 per year, the maximum which a 'Native' could receive in those days. In 1877, he received from the British Government the title of 'Rao Bahadur' on the occasion of the Delhi Durbar. He died on 19th March, 1884, at the age of 60. He was popularly known as 'Nānā'. His lifelong scholarly habits and his innate goodness were the most notable and praiseworthy among his many fine qualities.

#### Works.

About Śaka 1772, Nānā compiled in Marāṭhī, a work entitled, *Graha-sādhanaḥ Koyāke* (Planetary Tables) with the help of French and English works on astronomy, and published it in Śaka 1782, (1860 A.D.)\*. There was no such work compiled before, either in Marāṭhī or Sanskrit, and hence it ranks very high among works of similar nature.

\*Kṛpāśāstrī Godbole writes that it was compiled on the basis of a work published by R. S. Vince in 1808 A.D.

In this work, the length of the year is assumed to be the same as in the *Sūrya Siddhanta*; and the positions and motions of planets have been adopted on *śāyana* basis. Hence, the planets' places calculated from this work are asked to find the *nirayana* places of planets, by assuming the *ayanaṃśa* to be zero in that year, and by applying the *ayanaṃśa* correction to the *śāyana* positions at the rate of  $50''\cdot1$  per annum. The whole process amounts to the adoption of the correct length of the sidereal year, viz.,  $365^{\circ}15'23''$ . Adopting this length of the year and  $50''\cdot2$  as the annual rate of precession, Keroṣant Nāna began to publish since Śaka 1787 a separate almanac with the help of the Nautical Almanac. The late *Abdāsheb Patwardhan* gave him very valuable help. It was due to his encouragement that the above work could be compiled and the almanac was published from year to year. The almanac was naturally entitled by Nāna as 'Patwardhani Pañcāṅga'. The positions of planets calculated from Nāna's work is fairly accurate; but the work and the Patwardhani Pañcāṅga are not now in use, and it may safely be said that no one follows the almanac. This almanac will be described in more details further on.

Nāna compiled a work on the calculation of tithis on the lines of the *Tīthi Cintāmaṇi*. It has been printed in Vārāṇasī. No one could be found in this province to print it. It is almost unknown in this province, and this work as well as the *Grahasādhanaśi Kōṣṭha* are both out of print at present. The *Graha Sādhana* has not adopted the purely sidereal year and the places of planets are *śāyana*. Hence, the work, as it stands, is of no use in directly computing a Pañcāṅga belonging to any of the schools, viz. *nirayana* according to the *Grahalāghava*, purely *nirayana* or purely *śāyana*. Besides this it requires the use of logarithms and trigonometry; and hence, the orthodox astronomers are unable to make calculations from the work; and it is doubtful if even half a dozen persons could be found among the newly educated people who could calculate from it.

Nāna wrote two books for Marāṭhī schools. They are:—(i) Physics and (ii) Arithmetic. *Mahātāṣṭra* can boast of thousands of people who could be called his disciples, direct or by tradition.

### VISAJI RAGHUNĀTHA LELE, Birth Śaka 1749.

#### Brief Account.

One of the most talented and ingenious astronomers that ever flourished in our country, Lele was born at *Nasik*, on Friday, the tenth lunar day of the dark half of Śrāvana, in Śaka 1749 (i.e. 1827 A.D.), the ascendant at birth being Capricorn. He was a *citrāvan* Brāhmaṇa of the *Hitanyakesī* Branch of *Kāśyap gotra*. In his childhood he received some education in the Marāṭhī school at *Nasik* till he was 11, where he learnt arithmetic up to fractions, and he received some lessons in Sanskrit while residing with his maternal uncle. This was the only education imparted to him by teachers, but owing to his perseverance and intelligence he was able to solve mathematical problems that would baffle even University graduates in spite of their background of English education.

Lele was known to me personally and through correspondence. Most of his account has been taken on the basis of this personal contact. A sketch of his life was published in the October 1888 issue of the monthly journal *Balbooth*.

Having passed some years in some trivial employment, he went to Gwalior about Saka 1782. He was there employed in the Revenue Department and the Accounts Department of Scindia Govt. His Balboddh and Modī handwriting was excellent. He was also very good at map drawing; and not a single mistake was ever found to have crept into his accounts. Having put in 33 years service he retired about Saka 1816 and he died at Gwalior in his 69th year, on Friday the 6th lunar day of the dark half of Kārtika in Saka 1817.

#### Sāyana Pañcāṅga

Many persons feel that the almanac should be sāyana. Many must have felt and did actually feel thus before Lele. The thought naturally crossed Lele's mind and he was convinced that the 'sāyanapañcāṅga, alone could be said to be in conformity with the tenets of religion. For some days, he used to compile a sāyanapañcāṅga for practical use with the help of the *Graha-laghava*, and later on with that of the *Nautical Almanac*. But he did not get any opportunity for publishing it for some years. He had acquired a working knowledge of English that enabled him to compute figures from the *Nautical Almanac*. Keropant began to publish an accurate nityāṅga almanac from Saka 1787 (i.e. 1865 A.D.). From that year Lele carried on a controversy with Keropant through the press under the nom-de-plume "Sphutavakṣa Abhiyogi", (candidate combatant) in order to convert Keropant to the Sāyana view. Keropant remained indifferent and Lele, finding that he (Keropant) did not appear to be impressed by the importance of publishing a sāyana pañcāṅga, which would conform to the tenets of religion, began to publish independently a sāyanapañcāṅga with the help of other co-workers from Saka 1806. We shall have to revert to this almanac later on in the chapter on *Pañcāṅga*.

Lele did not compile any work from which to compute a sāyanapañcāṅga, and hence, the task of popularizing it is a matter depending upon outside factors.

### CINTĀMANI RAGHUNĀTHA ĀCĀRYA

(Birth Saka, 1750)

Brief Account.

He was for 17 years the First Assistant in the Astronomical Observatory at Madras. Cintāmanī Raghunātha Ācārya was an authority in the Madras Presidency just as Keropant was in this province and Bāpudeva in the region around Vārāṇasī. He was born on the 6th day of the PAṆGUṆI month of the Sarvajit Sāmvatsara in Saka 1749, according to the solar reckoning, or on the 2nd lunar day of the bright half of Caitra of Saka 1750, by the luni-solar reckoning i.e., on 17th March, 1828. His mother tongue and the birth region appears to be Tamil (Dravid). He has himself written that he did not understand Sanskrit. Still he had a very sound knowledge of European astronomy and mathematics, and hence, that of Indian astronomy also. He actually used to take observations for a number of years. He was very well known in that respect. He was a Fellow of the Royal Astronomical Society in England since 1872. In 1847, he entered service in the Madras Observatory and he remained there till the end. He died on 5th of February (i.e. Paṅga) in Saka 1801, in his 52nd year. He belonged to a family of astronomers. His father

also had been an Assistant in the Madras Observatory. A catalogue of stars has been compiled by the Madras Observatory, for which observations of many of the stars were taken by Cintamani himself. He discovered two variable stars in 1867 and 1878. He was the first Hindu astronomer whose name is associated with a discovery of this nature.

#### Works etc.

He compiled a work entitled *Jyotiṣa Cintamani*. It consists of three parts. The first deals with mean motions, the size and magnitude of the earth and other planets etc. The second is devoted to their true places and motions and the third, entitled 'Karaṇa paddhati', contains tables for planetary calculations. This work appears to have been compiled in the Drāviḍian (i.e., Tamil) language originally. A meeting was held in Madras in 1874 A.D. and the decision taken to arrange to publish its Sanskrit translation in the Tamil, Telugu and Devanagari scripts. It was estimated that the cost of the publication would be Rs. 7,000 for 500 copies, the whole work comprising about 800 pages of demi octavo size. The book however, was never printed.\*

He used to publish an almanac, entitled *Dygganīta Pañchāṅga* with the help of the *Nautical Almanac*. The author has seen an almanac for Śaka 1808, published after his death by his two sons. It seems to have adopted 22°5' as the *ayana* and the length of the year as given in the *Sūrya Siddhānta*. The elder son C. Rāghavācārya died about Śaka 1811. His younger son and brother-in-law, P. Rāghavācārya, the First Assistant in the Madras Observatory, jointly publish the almanac at present.

#### KRṢṆA ŚĀSTRĪ GODBOLE, Birth Śaka 1753.

##### Brief Account.

He was a Citpāvan Brāhmaṇa, belonging to the Hiraṇyakeśi branch and of the Kauśik gotra. He was born on the 10th lunar day of the dark half of Śrāvana, Śaka 1753 (i.e., on 1st September 1831) at Wat. He studied, in the beginning, in a Marāṭhi school at Poona and then at the Sanskrit Pāṭhśālā and the Poona College. He had a liking for mathematics from his very childhood. At the Sanskrit college he studied astronomy under the care of Śankar Jōṣi. On the 19th of October, 1855, he was appointed a teacher in the Normal School of the Poona College. There he mainly taught mathematics. For some time during 1864-65, he had been appointed in the Colaba Observatory, Bombay. In 1865 he was again appointed in the Poona Training College. In 1866, he was transferred to the Hyderabad High School, Sind, and in 1867 to a High School at Karachi. In 1872, he worked as Asstt. Teacher in the Poona High School and later on for some days more in the Elphinstone High School, Bombay. Later on, in the same year, he was made the Head Master of the Anglo-Marāṭhi School, Phanaswādī, Bombay, and he remained there till March, 1882. Later on, he began to reside in his home at Poona, after

\*In 1874, there was a transit of Venus across the disc of the Sun. Rāghunātha Acārya had got his calculation published in several languages. His pamphlet in English contains an account of this laborious task. The author has given the account of Rāghunātha Acārya, mainly on the basis of this pamphlet and also from the information published in newspapers and sent to him by the well-known Nates Śāstrī of Madras.

his retirement from Service. He died on 22nd November, 1886. While he was in Sind, he studied the Sindhi language thoroughly and learnt even Persian. He used to be an examiner for the Sindhi language, in the Bombay University, from 1871 to 1879.

#### Works.

He and Wāman Kṛṣṇa Joṣi Gādre, jointly translated the *Grahaṅghava*, with examples, into Marāṭhi and published it in Saka 1778. It is almost a translation of the Viśwanāthi commentary. A second edition of this work is now published. Kṛṣṇa Sāstri has also written a book on the theory underlying the *Grahaṅghava* in Marāṭhi and it is learnt that he has corrected in it the errors in the Mallāri commentary. It is worth publishing. In addition to this, a short article of his, on the history of astronomy, written about Saka 1807, has come to the author's notice. The *Jyotiṣśāstra*, a Marāṭhi book written on the basis of Chambers's book in English, was printed and published in 1862 A.D., but it is not now in use. A Marāṭhi translation of *Hudson's Algebra*, had already existed; he published it in 1854, after correcting it. It was in use in the Education Department for several years. In 1874 A.D., he and Govind Vihārī Karkare translated in to Marāṭhi four parts of Euclid's geometry. Before this date, a Marāṭhi translation of Euclid's geometry by Nānāśāstri Aptē was in use in schools. Later on, from 1885 A.D. the book, by late R. M. Devakule, came into use. In 1882 A.D. Kṛṣṇa Sāstri published an article entitled "Antiquity of the Vedas" in the Theosophical magazine and also got it printed separately. The author does not think that it contains any evidence on the strength of which it could be proved beyond doubt that the Vedic period was more ancient than 1200 B.S. (before Saka). He attempted to prove that the antiquity of the Vedas extends beyond 30000 B.S., by interpreting the line "masānām Mārgaśīrṣoham" from the Gīta, as indicating that "the equinox used to occur in Mārgaśīrṣā". He published a book on Arithmetic in Sindhi in 1869 and a good book on Marāṭhi Grammar also in Sindhi in 1867 A.D. Its popularity is proved from the fact that it went through its third edition in 1895\*. He also published in 1868 A.D. a book on the Sindhi language.

He had once published his view that the calculation for the five parts of the *Pancāṅga* should be made on the basis of the mean places of the Sun and the Moon.

Wāman Kṛṣṇa Gādre, referred to above, published in Saka 1791, a work entitled *Pancāṅga-sādhana-sar*. It contains a Marāṭhi translation of the *Laghu Cintāmaṇi*, along with examples. The tables, however, contain a good many errors.

#### Living Authors of Astronomical Works.

1. Venkates Bapuji Keikar :—  
(Birth date :—Friday, the 14th lunar day of the bright half of Pausa, Saka 1775).

\*This has been printed by Ananta Kṛṣṇa, the son of the Sāstri, who has given in it, the biography of Kṛṣṇasāstri. The above account has been given on the basis of the biography as well as the information collected by the author.

He is a Rġvedī Citpāvan Brāhmaṇa belonging to Gārgya gotra. He is working as a teacher in the Education Department in this province since 1874 A.D. He has been the Head Master of the English High School, at *Bagal-Kot*, for the last several years. He received most of his education at Beigaon. His father also was a good astronomer. He had rendered into Sanskrit Keropant's Planetary Tables, but it was not printed. For the last five or six generations the family had been living at Patihān. But Bāpu left the place for Nargundas and later on shifted to Rāmdurgas. He had the patronage of the Chief of that State.

Venkates compiled a very useful work in Sanskrit, entitled "Jyotiṛ-gaṇita" about Saka 1812. He has adopted in it, Saka 1800 as the epochal year. This has been compiled on the basis of those French works which are being used in compiling the *Nautical Almanac*. The planets' places, calculated with the help of this work, are very accurate, in fact they are correct within 1' as compared with those of the *Nautical Almanac*. Never before has such a work been compiled in this province, not even in our country. This work has adopted for the length of the year the correct value of the sidereal year viz. 365d-15-22-53 and 50".2 (the actual value) as the annual rate of precession. Assuming Zeeia Piscium to be the junction star of Revati, he has given its sāyana longitude, or in other words, the ayanāṃśa for the Saka year 1800 as  $18^{\circ} 10' 25''$ . The author had suggested to him to adopt for the ayanāṃśa a figure approximately equal to that of the *Grahaghāva*. A star whose longitude would be equal to it could have been adopted as the initial point. But even Ketkar has come to realise the fact that the ayanāṃśas can be nearly equal to those of *Grahaghāva*, by assuming  $180^{\circ}$  as the longitude of the star Citra (Spica). In short, if he had assumed  $22^{\circ}$  as the approximate ayanāṃśa for Saka 1800, the author feels that Ketkar's work would have easily come into general use. The work mainly consists of four parts. The first contains the calculation of the almanac. The epochal positions are all given for the moment of the true Aries Ingress. The second part treats of the calculation of the places of planets. It includes the mean and true longitudes of planets, the right ascension, longitudes of star etc., heliacal rising and setting of celestial bodies, and other subjects. The third contains the calculation of phenomena like eclipses, conjunctions, elevation of moon's cusps. The fourth contains the calculation of the ascendant etc. required in the case of three problems. The treatment of each subject has, everywhere in the book, adhered to the following order:—Method, example, tables and then the theory. The work contains tables for almost all calculations, and the calculators who do not understand the use of trigonometry and logarithms can easily make calculations from the book. Keropant's almanac can be compiled with the help of this Book. This book has not been printed as yet.

## (2) *Bal Gangādhara Tilak*

(Date of birth:—Wednesday, the 6th lunar day of the dark half of Āṣāḍha of Saka 1778, the ascending sign being Cancer). He is familiar not only in this country but even in foreign lands. He was for many years the Chief Professor of mathematics and astronomy in the Fergusson College.

He wrote a book in English entitled *ORION*, in 1893 A.D. (Saka 1815) in which he has discussed in an accurate and elaborate manner the question of date of the Vedas and shown that some of the Vedic hymns were compiled when the vernal equinox was situated in the Orion group of stars, that is, about 4000 years B.S.

(3) *Vināyak Pāṇḍurang Khāṇāpurkar* :—(Birth in Saka 1780).

He was a Rīgvedī Deśastha Brāhmaṇa, belonging to Jamadagnya gotra and a resident of Khāṇāpur, in Satara district. He has studied Sanskrit, astronomy and other subjects in the orthodox manner and also European mathematics and astronomy under the guidance of Keropant Nāna Chatre and Rājaji Moreśwar Devakule. An Association known as the Veda-Sāstro-ttejak-sabhā was started in Poona from Saka 1796 and he was examined by the Association in the subjects of Indian Astronomy and Sanskrit Grammar.

He has compiled a *rajak* work, entitled *Vainayakecyā Dwādaśādhyāy*, by which the annual reading of a horoscope can be given with ease. He has similarly written the following books in Sanskrit :—The *Kundasar*; the *Ardhakaṇḍa*, a versified Sanskrit translation, of the general enunciations of all theorems in the two parts of Euclid's Geometry, and the *Siddhāntasār*. In the last named work, he has explained the question of the movement of earth etc. according to the modern European view. He has translated into Marāṭhi, Bhaskara's *Lilavati*, *Bija* and *Golādhyāya*, adding an explanation of the theory and he is at present translating the *Gaṇitādhyāya*. These works are not yet printed.

(4) *Sudhākara Dwivedi* :—(Date of birth :—Monday, the 4th lunar day of the bright half of Caitra, Saka 1782).

He is at present the Head Teacher of mathematics and astronomy at the Sanskrit College, Vārānasi. He was appointed in the place of Paṇḍit Bāpūdeva, after his retirement in Saka 1811. He was formerly the Chairman of the Library Committee in the same College. The title of Mahamahopādhyāya has been conferred on him by the British Government.

The following are the Sanskrit works compiled by him :—(1) The *Dirghavṛttalakṣaṇa* (Saka 1800). The author described in details the properties of the ellipse, along with its theory; (2) the *Vicitra Prasna* (Interesting problems), This contains 20 difficult problems in mathematics, along with their solutions; (3) the *Vāstava Candra Stygonmat-sādhana*. After pointing out the defects in the calculation of the elevation of the moon's cusps by the methods advocated by Lalla, Bhaskara, Jyānārāja, Gaṇeśa, Kamalakāra and Bāpūdeva, he has given in this, the correct method of calculating it accurately with the modern methods of European astronomy. This contains 92 verses; (4) the *Dyucara Cāra* (Saka 1804). This contains a discussion of the orbital paths of planets according to modern European astronomy; (5) *Pīṇḍa-Prabhākara* (Saka 1807). This is a work devoted to the subject of house building; (6) the *Bhābhramarekhaṇḍirūpaṇa*. This is devoted to the consideration of the subject of "Sūcti-Chedana" corresponding to a given shadow; (7) the *Dharmābhrama*; It considers the diurnal rotation of the earth; (8) the *Grahana Kāraṇa*. This describes the method of calculating an eclipse; (9) the *Golīya*

*Rekhaganita* i.e. Spherical Geometry; (10) A Sanskrit translation of the 6th, 11th and 12th books of Euclid, in verse form, and (11) the *Ganaka Tarangini* (Saka 1812). It contains a history of Indian astronomers. It was, in the beginning, published in *Pandit*, a monthly journal of Vārāṇasī. It was published separately in book form later on in Saka 1814 and contains 124 pages of octavo size. Most of the remaining works have been printed. The following are the commentaries edited or written by Sudhākara:—He edited the *Yantarajya* in Saka 1804, along with the commentary, *Pratibha Bodhak*, dated Saka 1795, as also the commentary by Malayendrasuri. He published Bhāskara's *Līlāvati*, with a new theory and certain special features in Saka 1800. He also published Bhāskara's "Bija" with a new commentary. He wrote a commentary, "Vasana Vibhūṣaṇa" on Karāṇa Kutubhala, which was printed in Saka 1803. He wrote in Saka 1810, a commentary named "Pañcasiddhāntikā Prakāśa" on Varāha's *Pañcasiddhāntikā*. The work containing the commentary, along with an English translation of the original by Dr. G. Thibaut, the then Principal of Vārāṇasī Sanskrit College, was published in 1889 A. D. All these commentaries are written in Sanskrit. In addition to these, he edited and published the "Chāḍak Nirṇaya" by Kṛṣṇa, "Siddhāntatattva-vivēka" by Kamalākara and "Dhivṛddhidā tantra" by Lalla, in the Saka years, 1806, 1807 and 1808, respectively. He is at present engaged in getting the revised edition of the *Bīḥat Saṃhitā* with Utpal Tika through the press. He has compiled a work, "Bhāṣā bodhaka", in Sanskrit, about (the teaching of) a language. He has written two books in Hindi, on Mathematics, entitled *Calan Kalan* i.e. Calculus, and has also compiled a Hindi Grammar.

The *Ganaka Tarangini* by Dvivedi is on the whole a useful work. From this and from all his other works his profound knowledge of Indian and European mathematics and astronomy becomes evident. Still, he has, at places, passed some baseless and fantastic remarks in the *Ganaka Tarangini* such as the following:—"Aryabhata introduced the system of denoting numbers, by a new code with a view to keeping secret the numbers of revolutions and other elements which he secured through the favour of some Greek scholar whom he revered as a deity", or "Bhāskaraśārya has described the origin of *jya* at the end of his work, without explaining the underlying theory. It can be surmised from this that he learnt from some Greek traveller only the method and not its theory". He has the ability to compile a work in Sanskrit on the lines of the French works, which are being used in compiling the English *Nautical Almanac*. It is desirable that he should compile one himself.

#### FURTHER INFORMATION ABOUT AUTHORS AND WORKS BELONGING TO PERIODS PRIOR TO ŚAKA 950

After about 250 pages of the present work were printed, the author came across two or three books not seen before, which contain information about some astronomical works and he proposes to give here extra information collected from them. Mahomed of Ghazni had brought to India a Muslim scholar, named, *ABU AL REHAN MOHOMED BIN AHMED AL BERUNI*. He was born at Khiva in 973 A. D. He became a Minister to the King of that State. Later on, the province was conquered by *MAHMUD* and *BERUNI* was brought to India, as a man under surveillance. Beruni lived in India from 1017 to 1031 A. D. He wrote a work in Arabic, entitled *INDICA*, about the year 1031-32 A. D. (i.e. Saka 953). It contains a description of several sciences

then known in India. Berru had learnt Sanskrit and had studied several works written in Sanskrit. He had paid special attention to astronomy and translated some astronomical works into Arabic. Edward C. Sachau, a Berlin Professor has translated his work, "Indica" into English. It has been published in two volumes. The author gives the information gathered mainly from this work about authors who lived before Saka 950.

### SPREAD OF HINDU ASTRONOMY AMONG MUSLIMS

The Sind province was under the control of the Caliphs of Baghdad for some years. During the reign of Caliph *MANSOOR* (753 to 774 A. D.) some ambassadors were sent to his court by the ruler of a State in Sind in 771 A. D. They were accompanied by some astronomers. It was at the hands of these astronomers that some astronomical works in Sanskrit were translated into Arabic. A Hindu astronomer was staying at Baghdad in 778 A. D. During the reign of Caliph Haroun (786-806 A. D.) also some Hindu works on medicine and astronomy were translated in Arabic. It appears that in those days Brahmagupta's *Brahma Siddhanta* and *Khapṛakṛhādya* had already been translated and independent works were compiled in Arabic with the help of different Sanskrit astronomical works.

The Arab astronomers *AL FAZARI*, *YAKUB-BIN-TARIQUE*, and *ABU AL HASAN*, lived in the latter half of the 8th century A. D. They compiled astronomical works in Arabic with the help of the Indian astronomers referred to above. These works are not at present available; still Berru had with him the works written by these three astronomers. He has often referred to the works written by the first two. Those works contained several of the following subjects usually found in Sanskrit works, viz. measures of time, numbers of the revolutions of planets in *Mahayuga* or *Kalpa*; lengths (in *yojanas*) of planetary orbits, calculation of *ahargana* for finding the mean positions of planets; sines of angles; rising and setting of planets; first visibility of the moon, etc. The Arabs first learnt astronomy from the Hindus and then they came to know of Ptolemy's work. *Al Fazari* was the first to teach Hindu astronomy to Mahomedans. The *Khapṛakṛhādya* had already been translated into Arabic when *Yakub* compiled his work. That translation may have been made by *Al Fazari*.

### THE PULISA SIDDHANTA.—

Berru had this *Siddhanta* with him together with a commentary on it. He was translating it into Arabic. He has given the number of revolutions of planets and those *savana* days in a *Mahayuga*, etc., as mentioned by *Pulisa*, and they agree entirely with those cited by *Utpala* as belonging to *Pulisa Siddhanta*. These numbers have been mentioned before (page 18). They do not contain the numbers of the revolutions of *Rahu* and moon's apogee which have been given by Berru as 488219 and 232226 respectively. The longitude of the sun's apogee has been stated to be 80°. Berru states that the *Pulisa Siddhanta* describes the *yuga* system according to the *Smritis*, but it gives 1008 as the number of *Mahayugas* in a *Kalpa* and 14 *Manus* consisting of 72 *Mahayugas* each. The 'twilights' (*Sandhyas*) and 'semi-twilights' (*Sand-*

dhyanas) are, of course, absent, and the Yuga is supposed to begin at midnight. He says "I think that Pulisa siddhanta is the name given after Paulis, the Greek resident of the city of Samtra, and that Samtra is the same as Alexandria." But he also observes that the Greeks had no yuga system among them. It clearly shows that Utpala's Pulisa siddhanta was widely used at the time of Berni.

**ARYABHATA I** :—Berni cites the numbers of revolutions of planets given in Abu-al-Hasan's work and most of these tally with the numbers given by Aryabhata I ; and those that do not differ probably through the errors of copying. Berni had with him some part of the work Aryabhata's and its Arabic translation. This translation must have been made during the reign of Caliph Mansur.

**VARAHA MIHIRA** :—Berni has given Saka 427 as his date. Berni had translated his works Brhatsamhita and Laghubhata into Arabic. The commentary on the *Bhujjataka* by Balabhadra has been referred to by Berni. Sudhakar writes that Varaha's works *Yoga Yatra* and *Vidhapatala* are available at Varanasi. According to Utpala, there was a work entitled "Samasa Samhita" by Varaha. It may have been an abridged version of Brhatsamhita.

**BRAHMAGUPTA** :—On the basis of Berni's works, Prof. Sachau observes, "Brahmagupta occupies an important place in the history of oriental culture. Brahmagupta taught astronomy to the Arabs before they came to know of Ptolemy's works, since, references to the works 'Sindhind' and 'Al-Arkand' frequently occur in Arabic literature ; these are the translations of Brahmagupta's works, Brahma Siddhanta and Khanḍakhadaya". The translations may have been made during the reign of Caliph Mansur, and it appears from this, that Brahmagupta's works had a wide spread influence in the Sind Province. Berni has repeatedly referred to Balabhadra's commentary on Khanḍakhadaya. Berni had translated Brahma Siddhanta and Khanḍakhadaya into Arabic. He observes that the Arabic translations made before his time were not correct. These translations have not been available so far. Berni had lived mainly in Sind for a good many years. His remarks, at several places, show that Brahmagupta's works had a great influence in that province in those times.

**LALLA** :—The author of the *Ganaka Tarangini* also gives Saka 421 as his date. But it has already been proved (page 94) that it is wrong. Bhas-karakarya has, in the *Goladhya*, quoted Lalla's verse on the calculation of

\* (Berni has referred to the Aryabhata of Kusumpur and to another Aryabhata who lived earlier. The author could not obtain the work of the older one, but Berni remarks that the Aryabhata of Kusumpur was his follower. Both of them have been referred to by Berni at 30 places. After reading all those passages, it is found that the description completely applies to the first of the two Aryabhatas formerly described (page 51 and 95). The number of revolutions of planets and such other matters referred to by Berni as to differentiate one from the other very clearly, do not apply to the second Aryabhata, and he was not the follower of the first. From this it follows that the two Aryabhatas referred to by Berni are in fact, one and the same person. Even Prof. Sachau, did not note this fact pointed out here. The second Aryabhata who figures in the authors account, may have lived before Berni, and although it is evident that his work was not seen by Berni, it appears that he laboured under a misunderstanding due to hearsay reports about the existence of two Aryabhata. This leads to the inference that Aryabhata II, may have lived only a century or a half before Saka 950, and confirms the author's former estimate of his date.

Decan.

marked in the very beginning of the work :

नरका शिव स्वर्गविभवपादया गणितस्य सारमुद्धृत्य । लोकायवर्द्धिताय प्रवक्ष्यामि श्रुतार्थाय ॥

**Residence.**

the similarity of names. Mahāvīra has quoted Śrīdhara as follows :—

[illegible]

It is true that as the line is in 'anustup' metre it could not have occurred in Trisati which is compiled in Arya metre ; still it may have been borrowed from Śridhara's larger work on Paṭigaṇita or from his algebra. The Austrian Catalogue mentions "Trisatigaṇitasāra" as a work by Śridhara. It appears from this that Śridhara's work *Gaṇitāra*, procured by Colebrooke and the *Trisati* mentioned by Sudhākara are one and the same work. There is another work, *Trisatapaḍḍhati* attributed to Śridhara which may have been compiled by Śridhara, the author of the *Paṭigaṇita*.

\* This has been stated chiefly on the basis of the Ganga Tarangini.  
\*\* The text (pachayama) is found in a Bohnenagata's work.

4. The following information is found in the transcript:

**BRĀHMANĀNĀSA KARĀṆĀ:**—According to Berruṇi, the author of this work is Manu, and the work has a commentary by Utpala and it was reproduced in an abridged form under the name of *Laghumānasa* by Munjaī. As the *Laghumānasa* belongs to Śaka 854, Bṛahmaṇasa may have been compiled about Śaka 800.

**BALĀBHĀDRĀ:**—Berruṇi has given several quotations from his works or his commentaries. According to Berruṇi, he had compiled works on each of the sections "Gaṇita, Samhitā and Jātaka", and had written commentaries on the *Khaṇḍa Khadya* and the *Bṛhajjātaka*. The work on "gaṇita" has been called a "tantra" by Berruṇi, which indicates that it advocated the calculation of śharṅga from the commencement of Yuga. The quotations given by Berruṇi show that there was also a commentary by Balābhadrā on Brahmagupta's Siddhānta. Berruṇi has given quotations from the commentary on the "yoga-śāstra" of Patañjali, and Prof. Sachau infers that the passages were written by Balābhadrā as is indicated by the context; and as the major part of the passages is devoted to questions of astronomy, the inference seems to be correct. Balābhadrā's works mentioned the latitudes of *Kanauj* and *Sindhawar*, which indicates that he may have been a resident of that area. His date appears to be about Śaka 800.

#### KARĀṆĀSĀRA BY VITTEŚWARA (Śaka 821)

Vitteśwara, son of Bhadrata (or Mīdhātta) had compiled a work called *Karāṇasāra*. It has adopted Śaka 821 as the epochal year. According to Berruṇi, Vitteśwara was the resident of Nagpur. His work mentions 34°-9' as the latitude of Kashmir; and it refers to the motion of the Sap-tarṣi (the Greater Bear), on which the popular system of reckoning time, current in Kashmir, is based, and from this I feel that he may have been a resident of Kashmir. The *Karāṇasāra* described the method of calculating the mean longitudes of planets from the epochal planetary positions given for the moment of the mean Aries Ingress. Berruṇi has given the method (mentioned in the work) of finding the tithi at the moment of mean Aries Ingress (tithi-śuddhi) in terms of degrees, which can be explained if the number of revolutions of the Moon in a Mahāyuga be assumed to be 57753336. This number is given in the *Sūrya Siddhānta* the *Pulisaiddhānta* cited by Utpala, and the First Ārya Siddhānta. Berruṇi had with him the Arabic translation of the work made by some one else before his time. The *Aufrecht Catalogue* does not mention this work at all. From this it seems that it is not available anywhere now. There lived one Vitteśwara who was the author of some astronomical works; and this Vitteśwara mentioned by Berruṇi may have been the same as Vitteśwara.

**LĀGHUMĀNĀSA BY MUNJĀI (ŚAKA 854):**—Munjaī was a resident of the Deccan. He compiled *Laghumānasa* which was an abridged version of Bṛahmaṇasa. Berruṇi observes that it has adopted 6°-50' as the *ayanaṁśa* in Śaka 854 and 1' as the annual rate of precession. From this, according to Munjaī's view, the zero precession year comes to Śaka 444 elapsed. Berruṇi has stated the name of the author to be something like "Punjai". The author of the *Gaṇakāraṇāgiri* writes, "I have seen *Laghumānasa*, a short work of 60 verses in 'anuṣṭup' metre. It belongs to Śaka 854. The work does not mention Munjaī's name explicitly, but contains at the end the line 'thus ends (the

work) compiled by Munjal Bhatia. Colebrooke has recorded the dates of some astronomers as furnished by the astronomers at Ujjayini, according to which the date of Munjal is Saka 854. Bhaskaracarya has given the Laghumānasa referred to by Berni, is Munjal himself. Muniswara has given, in his commentary called Marici, the following quotation from Munjal :—

उत्तरी धाम्यादेर्ध्यात्प्रातस्तमः सौरादिभ्याम् ।

परिध्यात् प्रातस्तमः सौरादिभ्याम् ।

विषुवदक्षमण्डलस्य प्रातस्तमः सौरादिः ।

पञ्चविंशतिरात्रयकमण्डलः प्रातः ॥

सौरादिभ्याम् विषुवदक्षमण्डलस्य प्रातस्तमः सौरादिः ।

तत्र च परमा कतिचित्प्रातस्तमः सौरादिः ।

विषुवदक्षमण्डलस्य प्रातस्तमः सौरादिः ।

तत्राग्राः कल्पे सौरादिभ्याम् विषुवदक्षमण्डलस्य प्रातस्तमः सौरादिः ॥

“While the celestial bodies move in the sky from north to south and again from the south to north, a very small variation takes place in their declination. The (ascending) node in which the celestial equator and the ecliptic intersect is the First point of Aries, Mesādi and it gives the ‘East’. The second node is the first point of Libra (Tulādi), and these two points never change their declination value (which is zero). The first point of Cancer (Karkādi) is at a distance of three signs (i.e. 90° and after a distance of three signs more, comes the position of the first point of Capricorn (Makārādi). These give the positions of maximum declination which is 24 degrees.

The solstitial points (which mark the junctions of ayanas) show a movement, and the number of their revolutions in a Kalpa is counted as 199669.” These verses are in Aryāmetre, and they mention the number of revolutions of the ‘ayana point’ during the Kalpa, which is uncalled for in a Karana work. The author of *Ganaka Tarangini* states that these verses are not found in the copy of Laghumānasa which is composed in ‘anusup’ metre. In the beginning of Laghumānasa there are the following lines \*\* :—

प्रकाशितवर्षात्प्रातस्तमः सौरादिभ्याम् ।

“Bharadwaj, the best of Brāhmaṇas was well known like the sun giving light. I compile another Laghumānasa work which would give accurate results.” It appears from this that Munjal had compiled another work named *Manasakarana*. But Berni observes that the author of *Bṛhan Manasa* was one Manu. It is not known if the above verse should be interpreted as ‘Munjal after compiling a work Laghumānasa, compiled another work

\* Essays Vol. II, page 461.

\*\* The description of Laghumānasa given hereafter is based on *Ganaka Tarangini*. The author of the *Ganaka Tarangini* has mentioned the date of Laghumānasa, at some places as Saka 854 and at some others as Saka 584. The figure 584 is clearly an error due to oversight, as can be seen from the word ‘Kṛtaviha’ (854) occurring at two places in the work as Saka number and from other proofs also.

Laghu laghumānasa (i.e. a shorter version of Laghumānasa than the one existing before). The above 'āryas' may form Munjal's second work entitled 'Laghumānasa' or Munjal himself may have been the author of Bṛhan Manasa and it might have contained these verses.

The work Laghu Manasa contains epochal positions of planets true for the noon of Sunday, the first lunar day or the bright half of Caitra, Śaka 854 (elapsed). The planets' places are to be calculated from the aharāṇa. It contains 8 chapters dealing with the following subjects: — mean places, true places, tithi, three problems, conjunction of planets, solar eclipse, lunar eclipse, and elevation of moon's cusps. The above verse states that Munjal was a Brahmana, belonging to Bharadvāja gotra. It is a very important point to note that no available 'human' (pauruṣa) work compiled before Munjal's time, explicitly mentions the motion of the 'ayana'-point. Munjal has mentioned a special correction to be applied to the true place of the moon, which is not to be found in any other work. This shows that Munjal was a remarkably ingenious research worker.

The Government Library, Varanasi, has an incomplete copy of Laghu-mānasa containing solved examples. In these examples, the Śaka year 1494 has been adopted and the 'Dhruvaks' have been given for Śaka 1400. The correction due to ascensional difference and other corrections are applicable with respect to the town of Kāmpilya. According to Sudhākara, the author of this commentary may be Paramēśvara, the author of the commentary on Āryabhaṭīya, since the statement that "a commentary has been written on Laghu-Bṛhan Manasa" occurs in the commentary on Āryabhaṭīya. But this is not probable, because, the author thinks that Paramēśwar belonged to Māliabār. The above 'example' shows that Laghumānasaśakara was in use till Śaka 1500 in some territories.

**ĀRYABHAṬA II**:—It has already been shown (page 188, footnote) that he lived before Berruṇi.

**PRTHU SWAMI**:—Berruṇi writes, "Pṛthudak Swami is the author of some astronomical work; but the name of his work is not known to me." It shows that the commentaries written by Pṛthudak Swami were not well known in the times of Berruṇi at least in the Sind Province. Berruṇi has quoted a passage from the work of Āryabhaṭa of Kusumpur to the effect that Pṛthudak Swami adopted 120 yojanas as the distance of Kurukṣetra from ujjayini. Since none of the works of the two Āryabhaṭas mention Pṛthudak's name, it seems that this may have been a passage from a commentary on Āryabhaṭa's works. (It appears at many places that Berruṇi was led to believe that the matter occurring in the commentary, belonged to the original text). The commentary existed before Berruṇi and Pṛthudak lived earlier than the commentary. From this his date may prove to be somewhat between Śaka 850 to 900.

**BHĀṬOTPA**:—Berruṇi has mentioned some works of this author in addition to those enumerated by the author (page 101). They are:—The Karapānaka—Rahunmakarāṇa and Karapāṇa, and a commentary on Bṛhan Manasa. The names of Karapānaka works appear to be curious and the two Karapānaka could not possibly have been compiled by one man. Evidently there was some misunderstanding on the part of Berruṇi. He says that Bṛhan had compiled another work, Śrīdhava by name; there seems to be some error in the name of the work. Berruṇi has quoted measures of time

etc. as given in these works. He writes that there were still other works named Sridhava. He has given some idea of the questions dealt with in them, which suggest that these may be some works on 'omens' or on horary astrology.

#### KARANA TILAK BY VIJAYANANDI (Saka 888)

Beruni says that Vijayanandi, the commentator, who was a resident of Varanasi, compiled the work Karana Tilak. Beruni has described the methods of calculating aharaga given in the work, the calculation of mean places from aharaga, finding the discs of the Sun and the Moon for calculating eclipses, calculation of Mahapata etc. It contains subjects similar to those of the *Graha Laghava*, the epochal positions given are true for the first lunar day of Caitra Suka, Saka 888. Dr. Sehran writes in his notes that the method of calculating the aharaga is similar to that of the Pulisa Siddhanta. Vijayanandi remarks that stars like Dhanishtha and Uttarabhadrapada do not set even when they are in proximity to the sun. The *Aufrecht Catalogue* does not mention this Karana work. It seems that this Karana work is not at present available anywhere. The Vijayanandi referred to by Varaha Mihira was much more ancient than this Vijayanandi.

**BHANUBHATTI-BHARNARJU**—He has, according to Beruni, compiled a 'tantra' work, named *Rasayana Tantra*, and a Karana work entitled, *Karapa paratila*. Prof. Sachau believes that the author's name may be pronounced as Bharnuraja or even as Bharnuyasa. Varun's commentary on *Khapdakhadya* (Saka 962) has borrowed some Anusup verses, from *Bharnubhatti's* work and from the work "Tantra Rasayana". It is not explicitly stated there that the work "Tantra Rasayana" was compiled by Bharnubhatti himself, still, the context, shows it to be so; and hence, the Bharnuraja (Bharnuraju) referred to by Beruni and the Bharnubhatti referred to by Varuna appear to be the same person. His date may be about Saka 900. The *Aufrecht Catalogue* does not mention either his name or that of his work. It appears from this that the works are probably not available anywhere at present. The word 'tantra' in 'Tantra Rasayana' suggests that the work had adopted the method of calculating planets' places from the beginning of the Yuga.

**OTHER KARANA WORKS**—After enumerating the names of some Karapa works like the Karapa Chidamayi, Lokanada Karapa by Lokanada, Bhattila Karapa by Bhattila etc. Beruni winds up the description with the remark that "there are innumerable such works". This statement of Beruni supports the inference that have been drawn before (page 120). It was but natural that several Karapa works came into existence according to the needs of different times and places. They are not all available at present, and even if they become available, they would be of no actual use. They will, however, be found useful in tracing the history of our country in general and that of astronomy in particular.

#### OTHER WORKS AND AUTHORS BELONGING TO PERIODS

##### LATER THAN SAKA 950

**SRIPATI**:—Muniswara's commentary on Liliavati contains passages from original works which show that he had compiled works on eclipses and meteors. The following lines occur in these passages:—

Of the meteorology, which is a branch of astronomy, the following are the works which have been collected from the *Caraka Samgraha*.

This information has been collected mainly from the *Caraka Samgraha*.

**KĒŚAVA** :—Kēśava, the author of *Vivāhavṇḍāvana* (page127) has stated in that work, in the verse "Tribhāga śeṣe dhruvanāmi" etc, that the 'vyatipāta' type of 'mahāpāta yoga' occurs when the third part of the "Dhruva yoga" is still to pass. This condition was true when the anyanāṣas were about 12½; and in his commentary on the verse Gaṇeśa Daivajñya says, "this has been so stated because, the anyanāṣas at the time of compilation of the work were 12". This means that Kēśava, the writer of the work, Vivāhavṇḍāvana, lived when the anyanāṣas were 12, that is, about the Śaka year 1165. The work, in the chapter on Lagnaśuddhi, mentions 4-48 as the *palā-bha* of 'Narmadā' (a city on the bank of the Narmadā). The latitude corresponding to this *palābha* comes to 21° 48'. The latitude of Broach, a city situated near the mouth of the Narmadā, is 21°-41'. This shows that his place of residence in those days may have been a town on the bank of the Narmadā.

From this and from some other clues mentioned before (page 124), he appears to be a Gujarati. Though originally a native of Gujarat, he or one of his ancestors may have shifted to Maharashtra.

॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥ श्रीगणेशाय नमः ॥

Mahadeva, son of Bopadeva, a Brahmana belonging to Kaudinya gotra residing at Tryambak on the bank of the Godavari and enjoying an honorable position at the court, compiled the work, Kamadhenu, which follows the Brahma paksa and Aryapaks. It contains 35 verses and tables, and it gives the annual motions and special positions of planets. It is claimed that the title can be calculated by collecting figures from 22 tables.

## GANGADHARA (Saka 1356)

In the Kali year 4535 (i.e. Saka 1356), he compiled a tantra work, named 'Candraman'. It follows the modern Surya Siddhanta. There is a copy of this work in the Government Library Varanasi. It explains only the methods of calculating mean and true places of planets. It contains nearly 200 verses. The mean positions in it have been calculated from the number of lunar months. But the solar reckoning too appears to have been included in it. Gangadhara used to reside in the city of Sagar, situated between the rivers Kṛpāveṇi on one side and Bhimarathi on the other, both of them lying to the west of Śrī Śaila mountain, which is situated on the prime (Ujjayini) meridian. He was a Brāhmaṇa, belonging to Jambadagnya gotra. The names of his ancestors, from his father backwards were Candrabhaja, Bhājārya and Viṭṭhal. The astronomer, Śrī Candā, was born in this very family; Gangadhara was a follower of the Surya Siddhanta. He was in the good graces of the king of Vidyaṇpur. As 'Candramāna-Tantra' was very difficult to understand, his son Viṣṇuadhara recast the work into easily intelligible verses. Viṣṇuadhara's date is not given.

**NRSIMHA**—Rāma, brother of Gaṇeśa Daivajña, author of Graha-laghava, had a son, named Nṛsiṃha, (page 139). Rāma may have been a younger brother of Gaṇeśa Daivajña. Sudhākara writes that this Nṛsiṃha compiled in Saka 1480, a work entitled "Madhya-graha-siddhi" on the lines of Mahādeva's work "Graha-siddhi". It explains the calculation of the mean places only. The true places are further to be calculated with the help of Mahādeva's work. Kṛṣṇa Śastri Goḍbole observes in his Marāṭhī manuscript: "Nṛsiṃha, son of Rāma and grandson of Keśava Daivajña, compiled a work entitled Graha Kaumudi in Saka 1510. The date of birth of Nṛsiṃha is Saka 1470". One of the two dates, this one and Saka 1480, mentioned above, must be erroneous. Since Nṛsiṃha says that the planets places should be obtained after multiplying the difference between the given year and Saka 1480 by the annual motions, the latter date cannot be wrong. Nṛsiṃha may perhaps have compiled this work some years after Saka 1480.

## CHAPTER 2

## THE UNIVERSE

A general description of the Universe has been given in the INTRODUCTION (page XXIX of Part I) Now let the subject be discussed in greater details. It has already been told (page XXXI of Part I) that the motion of planets in their orbits has been assumed to be the same, and it is about 11858½ yojanas in one day. And it is also assumed that each planet travels in one Kalpa a length equal to the circumference of the circulating of the celestial sphere. In other words, the length of the celestial orbit is equal to the sum of the orbital lengths of the revolutions made by each planet in one Kalpa. Hence, the length of a planet's orbit is obtained by dividing the length of the orbit of the celestial sphere by the number of revolutions made by each planet in one Kalpa. The Surya Siddhanta gives the measures of orbital lengths as follows:—

"The orbit is really that path in the sky along which a planet appears to revolve round the Earth. The word "celestial orbit", however, does not convey that meaning. As a matter of fact, the celestial orbit has no independent existence. It has been assumed only to facilitate the calculation of the lengths of planetary orbits."

Planet	Orbital length in Yojanas.	Planet	Orbital length in Yojanas.
Moon	324000	Jupiter	51375764
Mercury's mean elongation	1043209	Saturn	127668255
Venus's mean elongation	2664637	Starry belt	259890012
Sun	4331500	Celestial sphere	187120808640000000
Mars	8146909		

### MOON'S DISTANCE FROM THE EARTH

All the siddhanta's except the first Arya-Siddhanta, give the same daily motion, in yojanas, to the planets. Still, as the number of days in the Kāpa vary with each siddhanta, the length of the celestial orbit and those of the planets also differ by a small quantity. It would be of no use to give all these figures, since they contain very little truth. Most of the data are merely imaginary. The moon's orbit, however, has not been determined by imagination. There is a great degree of truth in it. The length of 1' arc of moon's orbit in its plane, has been assumed to be equal to 15 yojanas by all except Aryabhata I. Hence the length of the complete orbit comes to  $(360 \times 60 \times 15) = 324000$  yojanas; and the mean radius vector of the orbit comes to 51366 yojanas. This is the moon's distance from the Earth. The radius of the Earth, according to the Surya Siddhanta, is 800 yojanas; hence, the moon's distance from the Earth is 64.46 times earth's radius. According to modern discoveries it is 50.96 times earth's radius. The distance of the moon from the earth and its orbital length, as determined by the authors of our siddhantas are so very near the truth that they deserve to be congratulated on having been able to establish such a correct measure.

The motions of planets in their respective orbits have been assumed to be the same and the lengths of orbits are found by dividing the length of the celestial orbit by the number of revolutions of planets in the Kāpa. This method is proportional to their orbits, that is, to the distance of planets from the Earth. But this is not true according to the modern astronomical theory. The modern theory established by Kepler and confirmed by NEWTON and others is that the square of the revolution period of the planet is proportional to the cube of its distance from the Sun.

### DISTANCES OF PLANETS FROM THE EARTH

The distances of planets from the Earth are given in our siddhantas. They are all

more erroneous. Our astronomers have not determined — lengths of planetary orbits and the periods of their revolutions after first determining the length of the *Celestial orbit* and the mean daily motions of planets in their respective orbits in terms of *Yojanas*, by actually taking observations. It is quite clear that they first determined the periods of revolutions and the length of the moon's orbit by observation, and then, on the basis of these figures they fixed the lengths of the planetary orbits and that of the circumference of the celestial sphere. The *Pāṇca Siddhāntikā* does not mention the lengths of the orbits of planets and that of the circumference of the celestial sphere in terms of *Yojanas* nor does it mention the length of the moon's orbit; it appears, therefore, that the original *Sūrya Siddhānta* never contained this information. The modern *Sūrya Siddhānta* does give these measures; and the author has arrived at the conclusion that the modern *Sūrya Siddhānta* existed before the *Pāṇca Siddhāntikā*. It is not, however, improbable that the lengths of planetary orbits may have been interpolated afterwards. Secondly all the *Siddhāntas* except the first *Ārya Siddhānta* have given 15 *Yojanas* as the length of the moon's orbit subtended by one-minute angle. Thirdly the positions of planetary orbits are fixed, and the planets always move through them. The places of the orbits do not change. Hence, the statement that all planets make a revolution of the sky only once in a *Kalpa* has no meaning. *Bhaṣa-karācārya* plainly remarks,

नक्षत्रादि-गणनाय न च कदापि यः क्षिति क्षितिः ॥

क्षिति क्षिति क्षिति क्षिति क्षिति क्षिति क्षिति क्षिति क्षिति क्षिति

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"The Universe may or may not be limited by the *Celestial orbit*. It is the writer's opinion that earlier astronomers have defined "the circumference of the celestial orbit" as equal to the total length in *Yojanas* moved through by a planet in a *Kalpa*."

Our astronomers fixed the lengths of the planetary orbits from that of the *Celestial orbit* and the time taken by each planet for making one revolution. The principle, assumed as basis, that the time of a revolution and the length of the orbit are in proportion, was not true, and hence, the measures of orbital lengths have proved to be wrong while the length of the circumference of the *Celestial orbit* is found to be utterly fictitious.

Although the measures of orbital lengths and consequently the planetary distances from the centre of the solar system are erroneous, as explained above, still the radii vectors of planets which are their distances from the centre of the solar system, mostly agree with their modern values, when calculated on the basis of the correction known as annual parallax whose values are given in our ancient works and which in fact are the variations affecting their true places as the result of these distances. This will be seen from the sub-joined table in which the measures given by

"An ancient work like the *Bṛhama Siddhānta* compiled in B.C. 530, does give these measures. Hence, it does not seem to have been an error into the *Bṛhama Siddhānta* later, they may have been to some extent altered."

Ptolemy\* are also noted :

Planet	Surya Siddhanta				Ptolemy	Modern
	even quadrant		odd quadrant			
Sun (or Earth)	·	·	·	·	1	1
Mercury	·	·	·	·	·3750	·3871
Venus	·	·	·	·	·7194	·7233
Mars	·	·	·	·	1·5190	1·5237
Jupiter	·	·	·	·	5·2174	5·2028
Saturn	·	·	·	·	9·2308	9·5388

The measures calculated from the Surya Siddhanta have been given above. The radii vectors of Mercury and Venus are calculated by dividing the length of the circumference of the epicycles of conjunctions\*\* by the lengths of the planetary orbit i.e. by 360 and those of the Superior planets by dividing 360 by the circumferences of the epicycles of conjunctions.

It has been remarked above that the length of the moon's orbit according to Aryabhata I is different. It is obtained as follows :

$$\frac{10 \times 60 \times 60}{10 \times 60 \times 60} = 10 \times 60 \times 60 = 36000$$

\*The length of moon's orbit in yojanas is given by multiplying the total number of signs (i.e. 12) by 30, 60 and 10".

In this it is stated that the number of minutes of arcs in the moon's orbit multiplied by 10 gives the length in yojanas. In other words, here 1' arc is taken to be equal to 10 yojanas, while other Siddhantas have taken it to be equal to 15. This appears to be contradictory to other Siddhantas at first sight, but in fact, there is no contradiction. The following table will show that just as the length of the moon's orbit given in other Siddhantas is  $3\frac{1}{2}$  times that given by Aryabhata I, so also are other measures :—

Yojanas according to First Aryasiddhanta

Diameter of the Earth	1050
Sun's disc	4410
Moon's disc	315
Yojanas according to Siddhanta Sivamuni	1581
	6522
	480

\* Ptolemy's figures have been taken from the translation of the Surya Siddhanta by Burgess, and the modern measures from the work of Leconte.  
 \*\* The lengths of circumferences of the epicycles and the perihelia have been mentioned later on. The question will be discussed at greater length later on in the chapter on true places.





\* The Mahābhārata book contains such quotations from Bhāskaraśāstra in the astronomy by J. B. Mohan contains such quotations from Bhāskaraśāstra in the original along with their translation.

As regards the views of the heavenly bodies observed from different places on the earth, it may be stated that the Pole star appears to be in the horizon when observed from any place on the Equator, and the planets and other celestial bodies appear to rise and set along a vertical circle. As one goes northwards, the north pole appears to attain higher altitudes, and the diurnal circles along which planets and other bodies appear to move, are seen inclined to the horizon. For an observer at the pole, the Sun and other (celestial) bodies, appear to move along circles parallel to the Equator; all these things are discussed in the Siddhāntas. The author does not give quotations from the original here for want of space. Again, most of the Siddhāntas discuss questions like these (i) what places in the northern hemisphere (i. e. places in what latitudes) can never see a particular portion of the ecliptic, (ii) what latitudes can never see certain signs of the ecliptic or (iii) what are the latitudes where the Sun is visible for 60 ghatis or even more, and for how many days. It is not necessary to repeat them here in detail.

## VIEWS OF THE SKY

All Siddhāntas works while describing the Universe, give a description of the seven oceans on the earth and seven continents along with mountains and rivers in them; but this, in fact, forms part of Geography, and hence, the author does not deal with it here for want of space.

## DESCRIPTION OF THE EARTH

The falling down of a body is here stated to be due to attraction. When Newton discovered the power of attraction possessed by the earth, what thing other than the falling down of a body to the earth, could have suggested to him the power of attraction possessed by the earth? He drew the inference that the planetary system revolves round the Sun on account of this power of attraction, and established the law of gravitation, after proving it mathematically; this further work (of research) was, however, not taken up in our country.

"The earth possesses the power of attraction. It pulls towards itself a heavy body in the sky and the latter appears to fall."

भूतत्वात्, गुरुत्वात्,

गुरुत्वात् गुरुत्वात् गुरुत्वात् ॥ ३ ॥

गुरुत्वात् गुरुत्वात् गुरुत्वात् गुरुत्वात् गुरुत्वात् ॥

He says,

Bhāskaraśāstra has assumed that the earth possesses the power of attraction.

## ATTRACTION

It is stated in the verse that some worlds remain in position because of the support of the wind. But it is not clearly stated that planets and stars are worlds. It appears that our astronomers did not have the idea that planets and stars are very heavy and expansive globes like our earth.



## REVOLUTIONS OF PLANETS

The cause of mean motions of planets has already been discussed above. The numbers of the revolutions of planets in the Zodiac during the period of one Kalpa or one Mahāyuga have already been given as mentioned by different Siddhāntas. There is a noteworthy point about Mercury and Venus; and it is that because they are always found near the Sun, their revolutions in the Zodiac are assumed to be always equal to those of the Sun; and hence, our authors of the works have assumed for them the same number of revolutions and mean motion as for the Sun. But having regarded the conjunction (Sighra) of Mercury and Venus as some planets, the numbers of their revolutions given by them in the works happen to be equal to those of their actual revolutions round the Sun; and although our astronomers had no idea that planets revolve round the Sun, it is worth remembering that they had given importance to the revolutions of the 'Sighras' of Mercury and Venus.

## LIGHT OF PLANETS

It is the view of our Astronomical science that planets have no light of their own, but that they receive it from the Sun. Aryabhata I observes

यद्ग्रहाणि ग्रीष्मिणि तद्ग्रहाणि तद्ग्रहाणि ॥  
ग्रहाणि ग्रहाणि तद्ग्रहाणि तद्ग्रहाणि ॥ ५ ॥

ग्रीष्मिणि

"Half the spherical portions of the earth, the planets and the stars lose their light in their own shadows. Their faces which are towards the Sun are illuminated in the proportion in which they are so directed."

In this verse it is stated that even the stars receive light from the Sun, which is a mistake. A great deal of discussion is, found in our works regarding the increase or decrease of the Moons' digits, and the elevation of Moon's cusps.

## VIKSEPAS OF PLANETS

The viksepas of planets which are the inclinations of their orbits with the ecliptic are given in some Siddhāntas in the chapter on mean motions. Therefore, the measures of different Siddhāntas are given here—

Modern	I Arya S. Brahma S. II Arya S.	Lalla's S.	Sid. Siro.	Siddhānta	Ptolemy	Modern
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Moon	4 30	4 30	4 30	4 30	5 0	5 8	47.9
Mars	1 30	1 30	1 50	1 46	1 0	1 51	2
Mercury	2 0	2 0	2 32	2 18	7 0	7 0	7.7
Jupiter	1 0	1 0	1 16	1 14	1 30	1 18	41.4
Venus	2 0	2 0	2 16	2 16	3 30	3 23	34.9
Saturn	2 0	2 0	2 10	2 10	2 30	2 29	39.5

The author has taken Ptolemy's values as given by Ptolemy in his translation of Siddhānta and the modern values are taken from Ptolemy's Table.



Mars and Jupiter are concerned, have given values nearer to the modern ones than those of Ptolemy. The values given in Brahmagupta and Second Arya Siddhanta are almost equal to the modern ones. The value for Saturn is wrong by a few minutes only. As regards the *Viksepa* values of Mercury and Venus, it was found that if Mercury occupies at present a position of maximum heliocentric latitude, then, at one position its radius vector attains the value of .3382 and at the other, .4114, and if in addition to this, its distance from the earth has attained the mean value, its true latitude respectively becomes  $2^{\circ}29'$  and  $2^{\circ}53'$ . The mean of these values comes to  $2^{\circ}38'$  and it agrees very closely with that given in our works. The radius vector of Venus at its position of maximum heliocentric latitude attains the values of .7193 and .7293. If at both these positions its distance from the earth attains the mean value, its true latitude would be about  $2^{\circ}28'$ . This also agrees with the value given in our works. The values given in the table in the column for "modern" values, were calculated by the author from the data in the English *Nautical Almanac* for the six years 1883 to 1888. It was only on two or three dates during these six years that when Mercury attained maximum value for its heliocentric latitude, its distance from the earth was also equal to or very nearly equal to its mean value; and in the case of Venus no such dates could be found. It shows that these values cannot be accurately found unless observations are taken for several years; and for this reason our astronomers deserve praise for having found out very accurate values. The nodes of planetary orbits have got some slight motion. Hence, if the maximum values of the latitudes of planets at the time of Brahmagupta and Aryabhata be calculated in the light of modern mathematics, the above Siddhanta values may perhaps prove to be nearer to the true values than what we found in this comparison. The above verses will show that the values given by the two Aryabhata are different from those given by Brahmagupta and this shows that the values have been found by them independently. It cannot be argued that the figures are different in the three cases because they have been set down at random. If no other proofs be forthcoming, even the *Viksepa* values given in the above table would be enough to show that our astronomers determined the values for inclusion in their works, actually after taking observations.

## CHAPTER III

## "AYANA CALANA"

OR

## DISPLACEMENT OF SOLSTITIAL POINTS

Even if at a certain time, a star is found to be situated near that point of the ecliptic, which is crossed by the Sun and the Moon while moving from North to South and vice versa, it will not remain there for all time to come; it will be seen shifting eastwards as years roll by. At the time of the *Vedanga Jyotisha* the Winter Solstice (W.S.) used to occur near the beginning of Dhanistha; but as time passed on, it began to take place near Sravana. At the same time as vector of Mercury is  $3871$  and that of Venus is  $7233$  (Loomis' Practical astronomy).

"A mere recording of the values of *Viksepa* as given in our works and the modern ones side by side does not amount to a real comparison. The writer has not seen any one comparable the latitude values of Mercury and Venus as he has done above.

the time of Varāhamihira it used to occur near Uttarāṣāḍha. This means that the solstitial point receded so many degrees. If one point of the ecliptic changes its place, all points on it would necessarily do the same thing. Consequently, the star which at one time would be situated near the equinoctial point, which is the point of intersection of the equator with the ecliptic, would be seen to have shifted its place forward as time would pass; but in fact, it is the equinoctial point which recedes. As the change in the position of solstitial point was first noticed by astronomers while observing the sun's 'ayana' i.e. the solstitial position, most of the astronomical works have termed this kind of change as "ayana calana". The astronomer Āryabhaṭa II and others have mentioned the number of revolutions of the 'ayana,' as if it were a planet. BHĀSKARĀCĀRYA has called this motion also 'Sampāt-calana' i.e. the shifting of equinoxes, while the European astronomers call this phenomenon "precession of the equinoxes". All astronomical works except that of Bhāskaraçārya have attributed this motion of solstitial points to the movement of the 'starry wheel'. In other words they thought that the starry wheel moves eastward through some degrees in some particular period of time. But Bhāskaraçārya observes: —

तस्य [ विषुवत्कालवर्धनस्य ] अथ वर्धनस्य । यद्यनवर्धन-

यामः प्रसिद्धा एव विज्ञेयस्य कालवर्धनस्य यामः ॥

गीतगोविन्द.

"Even that point (viz. the point of intersection of the equator with the ecliptic) has a shifting motion. The equinox recedes through as many degrees as the solstitial points".

This evidently shows that he assumes a retrograde motion for the node (i.e. the equinoctial point) itself. Even the modern European scholars hold that it is the equinoctial point which has this motion of displacement.

#### MEASURE OF DISPLACEMENT OF SOLSTITIAL POINTS

Varāhamihira has mentioned nothing about the 'ayana-calana' in his Pañca Siddhāntikā. It appears that the five old siddhāntas had mentioned nothing about it. But the modern Śūrya Siddhānta does mention it. It has been described there as follows: —

विषुव ३० क्षय २० यत् यामा चक्रं प्राक् प्रवर्तते ॥ तद्वर्धनवर्धनस्य ॥

यामावर्धनस्य ॥

यामावर्धनस्य विषुवतः अयनायामः ॥ तद्वर्धनवर्धनस्य ॥

यामावर्धनस्य ॥ १० ॥

विषुव ३० क्षय २० यत् यामा चक्रं प्राक् प्रवर्तते ॥ तद्वर्धनवर्धनस्य ॥

यामावर्धनस्य ॥ ११ ॥

यामावर्धनस्य विषुवतः अयनायामः ॥

यामावर्धनस्य



The modern Romans, Soma and Sakalyokta Brahma Siddhanta give 600 revolutions of the 'ayana' in one mahayuga. Their remarks about the displacement of the ayanas point are given below :—

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It is not here clear what we get after dividing 'n' years by 600, does the quotient denote so many signs, degrees or revolutions? If we assume recession through one sign in 600 years, it would give 600 revolutions in a Mahayuga and that seems to be the number intended.

*Aryabhata I* and *Lalla* make no reference to the *ayana*-motion in their works. *Brahmagupta*, while accusing *Śrīṣeṇa* and *Viṣṇucandra*, says,

.. h1h3k2

Bhāskaraśāstrya while commenting on Brahmagupta's notions about Ayanas motion, says :—

॥ नमो भगवते ॥

सौरसिद्धांतोक्तवैदिकमन्त्राभास्येन अगणपरिष्कारे कथं वर्तते:....

1 DGO/69

Bhaskara says here, that at the time of Brahmagupta, the *ayanams* value was very small and hence it is likely that it could not have come to his notice and adds that one may still ask why he did not take the rate of the precessor of equinoxes as given by S.S., just as he had taken figures for other measures on the authority of older authors? It is true that Brahmagupta nowhere mentions any correction on account of precession or gives any figure as the number of *ayana* revolution, yet the above verses of Brahmagupta and Pithudaka's commentary thereon clearly point to the fact that people before the time of Brahmagupta had begun to think over the problem of change in *Ayana* position. According to Brahmagupta the Sun's entry into a tropical sign was a 'Sampkramaṇa', and the 'end of *Sayana* *Mithuna*' was the Summer Solstice. (This has already been shown in authors' account of his works). Hence he has not at all taken into account the equinoctial motion.

Munjal's quotations in *Aryametre* have already been given (H. page 191). The number of revolutions of the '*ayana*' have been mentioned therein to be 199669. These couplets make no mention of the question whether the equinox makes a complete revolution or not. But assuming that the equinox makes a complete revolution, the explication of the longitude of the equinox would come to  $9^{\circ} 29' 37'' 40''' 8$  at the beginning of Kali era, the *ayanamsa* would be zero in Saka 449, and the annual rate of the precession would be  $59''.9007$ . All these things clearly point to the fact that Munjal held the view that the equinox made a complete revolution.

The *Laghunamasakaraṇa* of Munjal written in Saka 854, gives 'I' as the annual motion for precession.

The second *Aryasiddhanta* gives the revolutions of the *ayana* planet for Kalpa and describes in the following verse the method of finding *ayanamsa*,

अथयुद्धेः कालिदायस्य कश्चिद्वर्षं स्यात् ॥

अथयुद्धेः कश्चिद्वर्षं स्यात् ॥ १२ ॥

अथयुद्धेः

*Meaning*:—"Reduce the longitude of the '*Ayana* planet' to an angle less than 1 rt. angle. Find out the sine of the angle. The value is *Ayanamsa*. The sign corresponds to the sign of the 'anomaly'. (It is positive if the *Ayana* planet be in one of the first six signs, otherwise negative\*). After applying this correction to the planet, the values of *Ayana* *Cara* (ascensional differences or A.D., *Kranti* (declination) and *Lagna* (ascendant) etc. are to be calculated". This is similar to the method of calculating a planet's declination. All our *Siddhantas* and even the Second *Arya Siddhanta* regard 24° as the maximum value of declination. Hence according to *Aryabhata II*, the *ayanamsa* value never exceeds 24°. In other words, the "plus" *ayanamsa* figures increase from 0 to 24 degrees, then it diminishes up to zero. It further becomes negative and increases from 0 to 24 degrees, and again begins to diminish till it becomes zero. The equinox is to be supposed to be making a revolution through 96 degrees.

\*This convention about positive and negative signs has occurred in connection with planets in this very chapter.

According to the Second Arya Siddhanta the number of revolutions of Ayanā planet during a Kalpa are "masihagāmadha" i.e. 578159. Taking one revolution as equal to 96° the annual rate of precession would come to 46.3 seconds ; but since, the method of calculating ayanāṁśas is exactly like that of calculating declination, the rate of precession will not always be the same. Adopting the above mentioned number of revolutions, the yearly rate of motion of the Ayanā planet in the Zodiac would come to 2 min. 53.4 seconds, and the annual rate of precession would sometimes come to 69.4 seconds, sometimes to 6.1 sec. or even less. The Ayanā planet takes about 7472 years for one revolution. The rate of precession during the 10th part of the 1st period i.e. during first 187 years, would be 69.4". During the next 187 years it would be almost the same. In the 3rd period of 187 years it will be 63.7". It will thus gradually come to be 58.1", 52", 43.3" ; 30.6", 20.4" and 6.1". When thus the ayanāṁśas reach the figure of 24 degrees, they will diminish in value at a reversed rate of motion, they will again increase and will again decrease ; but our experience is otherwise. The ayanā-motion no doubt varies ; but the variation is very slight. There is no harm if it be regarded as always constant.

Aryabhaṭa II has, like Parāśara, cited 581709 as the number of ayanā revolutions in a Kalpa. According to this hypothesis Saka 532 would be the Zero-precession year ; and because ayanāṁśas are calculated by the method of calculating declinations, their value is never constant ; their mean value comes to be 46".5.

Bhaskaraṭārya has not given the number of revolutions of the equinox in a Kalpa, nor has he given his view\*\* whether the equinoctial point makes a complete cycle or makes an oscillatory cycle of 108°. It has been pointed out above that he has adopted the number of revolutions given in the S.S. He further says,

अयनवर्षं यद्वर्षं सूर्योत्थितः स एवार्धः (क्रियायाः) ॥

तद्वर्षं तद्वर्षात् : कल्पे गीर्वातवर्षोत्थितः १६६६६६ ॥ १८ ॥

गीर्वातवर्षात्.

"The displacement of the solstitial point, spoken of by Munjaī and others refers to this very point (viz. equinox). Its revolutions in one Kalpa are 199669.

After quoting the ayanā revolutions according to S.S. and Munjaī, in his commentary on the above verse he next observes":

अयं च यं च ते च यथायं यद्वर्षं यदा यदा तद्वर्षं तद्वर्षात् : ॥

"Whatever be the number of revolutions, the degrees which are obtained by skilled (astronomers) give the position of the equinox."

It is clear from this that he recommends one to accept the ayanāṁśas which one would actually get by observation at a particular time. Similarly, his remark in this connection that "any motion which one gets actually by observation should be accepted", shows that he means to say that the number of revolutions in a Kalpa should be determined according to the ayanāṁśas actually found. The author has not come across a single statement in which Bhaskaraṭārya

\*The number has been fixed after fully considering the variations in readings.  
\*\*Prof Whitney observes that Bhaskaraṭārya has mentioned 199669 as the number of revolutions of the equinox in one Kalpa (See page 104 Trans. of S.S.). But it is a mistake. Bhaskaraṭārya has given this number as that mentioned by Munjaī.

cārya has clearly said that the equinoctial point makes a complete revolution, nor does he say that it does not make a complete revolution. Bhāskara-cārya has taken 1 minute per year as the ayanamotion in the work *Karapa-kutubala* and has assumed  $11^{\circ}$  as the ayanamśa in Saka 1105. He thus appears to have taken Saka 445 as the Zero-precession year, as has been already mentioned before.

From the foregoing discussion of the question of ayanā revolution and yearly ayan-motion it can be concluded that according to (i) the five Siddhāntas such as the S.S., the annual precessional motion was  $54''$  (ii) Munjāl,  $59''.9$  (iii) Ārya bhata II  $46''.3$  and (iv) Parāśara  $46''.5$ . However, it would not be wrong to say that since Saka 854, the annual precessional motion was 60 seconds for all practical purposes, and most of the Karapa works compiled from that date upto now have given this rate for the ayanā motion. The Bhāṭṭi-ya-karapa and one or two karapa-works following S.S. have, however, adopted 54 seconds as the motion.

*Does the Equinoctial Point Oscillate or Revolve ?*

The question whether the equinox makes a complete revolution or not has been fully considered above. According to Munjāl, the equinox makes a complete round in the ecliptic in a retrograde direction. As already mentioned Colebrooke says that Pṛthūdaka, the commentator of Brahma Siddhānta, and Nṛsiṃha, that of Śiromaṇi, have quoted Viṣṇucandra, the author of Vasīṣṭha Siddhānta, as believing in the theory of the complete revolution of the equinox. According to the five modern Siddhāntas, including the S.S., the equinox does not make a complete revolution but it oscillates upto  $27^{\circ}$  east and west of Revati while according to Second Ārya-Siddhānta it oscillates up to  $24^{\circ}$  only. Although none of the Karapa works explicitly states that the equinox makes a complete revolution, the method of calculating ayanamśas adopted would give more than  $24^{\circ}$  or  $27^{\circ}$ , that is amounts increasing right up to  $360^{\circ}$ . No karapa work probably states that when the ayanamśas come to be more than  $24^{\circ}$  or  $27^{\circ}$ , the rate of motion should be supposed to be minus  $60''$ , or in other words, the ayanamśas should be supposed to be gradually less than 24 or 27 degrees. In accordance with Karapa works which assume Saka 445 as the Zero-precession year and  $60''$  as the annual rate of precession, the ayanamśas would be  $24^{\circ}$  in Saka 1885 and  $27^{\circ}$  in Saka 2065. They will be  $27^{\circ}$  in Saka 2221 if S.S. be followed, and according to Āryabhaṭa II and Parāśara they will be  $24^{\circ}$  in about Saka 2400. So the question whether the theory that the displacement of ayanā-point does not take place through the whole Zodiac is valid would be settled by actual experience after about 67 years or after 600 years at the most. The modern theory of European astronomers that the equinox makes a complete revolution is a well known fact and if this theory be correct the rainy season will be found to occur in Caitra-Vaiśākha after a lapse of time. No one will be able to deny the contention of the followers of the śāyana system in this respect and the occurrence of spring during the months of Mādhava & Mādhava (*i.e.*, Caitra-Vaiśākha) is the only thing acceptable to the Śrutis. Fearing that the acceptance of Munjāl's view would take them into a position contradictory to that approved by the Śrutis, the author of Marīci & others accused Munjāl and others for holding views contrary to the teaching of the Vedas, and they were, in their own way, right in doing so. But it is not within our control to force the equinox to make a complete or incomplete revolution; this point did not strike the author of Marīci and others. The Vedānga jyotiṣa has recorded the occurrence of the Winter solstice (W.S.) in the beginning of Dhanuṣṭhā. From this it appears that in those days, the equinox used to occur in the beginning of the fourth part of Bharaṇi comete-

lacion, i.e., at a point 23° 40' from the initial point. The Vedas describe the Zodiac as beginning from the Kṛttikās, which suggests that the equinox used to occur in the beginning of Kṛttikās then, i.e., at a point 26° 40' from the initial point. Formerly the equinox was in advance of Āśvini, and later on it began to occur behind it. This may have suggested that the equinox oscillates, and because the displacement of equinox which was recorded was only a variation of 24 or 27 degrees, or because the maximum declination is 24°, some of the authors of siddhāntas may have been led to assume that the equinox oscillates up to 24 or 27 degrees. Let, future experience show what it may be, but the theory of oscillation of equinoxes proved very useful in tiding over the temporary difficulty of admitting that the seasons would not conform to the teaching of Śruti as the result of the complete revolution of the equinox.

### ACCURACY OF AYANA MOTION

Let us now see how far the annual rate of ayana-motion and the year of zero-precission are accurate, as adopted by our astronomers. The annual ayana-motion is clearly the advance made by the Sun in the assumed length of the year after its two successive transits of the equinox. The lengths of years given by different siddhāntas have been fully discussed on page 13 while reviewing the Romaka Siddhānta of the Pāṇca Siddhāntikā group. The lengths of year known to Vedāṅga Jyotiṣa, Pītāmaha and Puliṣa had already gone out of use before the year Śaka 427 (i.e., before Pāṇca Siddhāntikā). It has already been pointed out here that Romaka's year was never in use in our country. Of other Siddhāntas, the length of Brahmagupta's year viz., 365<sup>5</sup>/<sub>158</sub> 30' 22<sup>1</sup>/<sub>2</sub> does not appear to have remained in use after Śaka 964. The remaining lengths vary from 365<sup>15</sup>/<sub>158</sub> 31' 15" to 365<sup>15</sup>/<sub>158</sub> 31' 24" and have remained in use from Śaka 1000 onwards. The length of the tropical year in the year 1900 A.D. is 365<sup>14</sup>/<sub>158</sub> 31' 53-25. This is the time taken by Sun to return to the same equinox. If we deduct this from the length given by S.S. viz. 365-15-31-24, the motion of the Sun during the difference of time would come to 58<sup>7</sup>/<sub>158</sub> 777\* or 58<sup>8</sup>/<sub>158</sub> approximately. If we accept the shortest of the lengths of the year in use from 1000 A.D., the annual "ayana-motion" would be less by .269 i.e. about 58<sup>5</sup>/<sub>158</sub> 508. If Brahmagupta's year measure be accepted, it would come to 57<sup>5</sup>/<sub>158</sub> 557 but the author is of opinion\*\* that the above year measure was not taken as the basis while fixing the yearly rate of ayana-motion. It is a fact that the measure of the tropical year is gradually diminishing. If we accept the length of the tropical year in Śaka 700 as basis, all the above "ayana-motions" will have to be reduced by about 0<sup>24</sup>/<sub>158</sub>. All things considered, if the annual rate of precession 58<sup>4</sup>/<sub>158</sub> be accepted, it will be found to be very accurate, since it is in keeping with the average length of the year adopted in our works, and both Grāhalāghava and Makaranda which are in use in more than half of India, adopt the length of the year given by modern S. S. Hence, the rate of precession dependent upon this year length which comes to 58<sup>6</sup>/<sub>158</sub> should be considered accurate. This will show that the figure of 59<sup>9</sup>/<sub>158</sub> adopted by Munjal as the annual rate of motion and 60" which is now in general use, appear to be sufficiently accurate.† In other

\* Kero pant has mentioned 58<sup>5</sup>/<sub>158</sub> 521 (see Planetary Tables page 32); but a small error seems to have crept in here.

\*\* The reason is given on page 216 later on.

† The difference in the place of the tropical sun computed by European measures and that found from Grāhalāghava, is in keeping with the excess of the adopted rate of precession over the calculated rate, viz., 1<sup>1</sup>/<sub>158</sub> 4.

words, our astronomers may be said to have discovered the rate of precession correct within  $1''.4$ ; and it will be shown later on in the history of the attempts made by other nations to determine the ayanamotion, that our astronomers did not borrow it from others and it is really very creditable to them that they discovered it as a result of their own independent efforts. This alone would suffice to falsify\* the arguments of those Europeans who charge Indians with being very backward in the work of taking observations. Even Colebrooke\*\* says that they (Hindus) made a nearer approach to accuracy than he (Ptolemy) had done.

#### Findings of other Nations Regarding the Rate of Precession

The discovery of the precession of the equinoxes is due to Hipparchus, who arrived at it about the year 125 A.C. by a comparison of his own observations with those of Timocharis, made about 170 years earlier. Its existence was afterwards established beyond doubt by Ptolemy, nearly 300 years later. Ptolemy mentions, in the seventh chapter of the Syntaxis, that having observed several bright stars in the zodiac he found that they had all increased in longitude to the extent of  $2^{\circ}40'$  during the interval of 267 years that elapsed between Hipparchus & himself. He hence inferred that the increase of longitude amounted to  $1^{\circ}$  in 100 years which implies an annual precession of  $36''$ , he moreover stated that Hipparchus had arrived at the same result. This was a very erroneous determination. The total increase of longitude, during 267 years, must in reality have amounted to  $3^{\circ}37'$ , a quantity greater nearly by  $1^{\circ}$  than that assigned by Ptolemy. As the discordance seems too great to be accounted for by errors of observation, many eminent astronomers have come to the conclusion that Ptolemy made no observations at all, that in fact his catalogue of the stars is no other than the catalogue of Hipparchus reduced to the epoch of 137 A.D. by increasing all the longitudes to the extent of  $2^{\circ}40'$ . Unfortunately there are circumstances which strongly tend to justify this serious charge. Delambre compared together the longitudes of the same stars inserted in Flamsteed's\*\*\* catalogue, and supposing the interval between these two astronomers to comprehend a period of 1553 years, he hence deduced  $52''.4$  for the annual value of precession. This result exceeds the true value by rather more than  $2''$ . Delambre then diminished Ptolemy's longitudes of the same stars by  $2^{\circ}40'$  and supposing the results to be the longitudes of Hipparchus, he instituted a comparison between them and Flamsteed's longitudes. Assuming the interval between Hipparchus and Flamsteed to include a period of 1820 years, he now obtained  $50''.12$  for the resulting value of precession, a quantity agreeing almost exactly with the modern determination. (This strengthens the inference that Ptolemy himself had made no observations.)

\*At several places in his notes on the translation of S.S. Frit. Whitley has simply poured ridicule on the Hindus in regard to the accuracy of their observations.

\*\*Essays, Vol. II, p. 411.

Birth (A.D.)	Death (A.D.)				
1646	1719	***Flamsteed :	An English Astronomer	.	.
1693	1762	Bradley	An English Astronomer	.	.
1723	1762	Mayer	A German Astronomer	.	.
1732	1807	Lalande	A French Astronomer	.	.
1749	1822	Delambre	A French Astronomer	.	.
1784	184	Bessel	A German Astronomer	.	.

The efforts of modern astronomers have been constantly directed towards obtaining a more accurate value of the precession of the equinoxes. Tycho Brahe fixed the annual precession at 51". Flamsteed made it 50". Lalande by comparing the longitude of Spica Virginis as assigned by Hipparchus with its longitude deduced from observations made in 1750, obtained 50".5 for the resulting value of precession. Delambre, by a comparison of the observations of Bradley, Mayer and Lacaille with his own observations, was induced to fix the annual precession at 50".1. Bessel who had studied the question very thoroughly fixed the annual value, in 1750 A.D. at 50".21129. In 1900 A.D. the value for 365½ days will be 50".2638.

Bessel has fully discussed the precessional motion and determined it to be 50".21129 in 1750\* A.D. The rate of precession in 1900 A.D. will be 50".2638 in 365½ days.

In the 11th century \*A.D. Arzuel, a Spanish astronomer, declared that the rate of precession was about 1° in 75 years i.e. 50" annually and also that the equinox oscillates east and west up to 10°. Another astrologer, by name Thabit Ben Korrah, (13th Century A.D.) held that the equinox oscillated within 22°, and still another astronomer of the 9th century thought that it moved through a circle of radius 4' 18" 43". The famous Arab astronomer, AL Butāni (880 A.D.), considered the equinox as oscillating at the rate of 1° in 66 years or about 55".5\*\*\* annually. Some Arab astronomers who lived before the time of AL Butāni thought the equinox to be oscillating 8° at the rate of 1° in 80 or 84 years (i.e. about 45" or 43" per year). AL Butāni's figure agrees with that of the S.S.

#### *Accuracy of Zero-precession year*

Let us see with what accuracy the years of Zero-precession have been determined by our people. The Zero-precession years according to different astronomical works are given below :—

Saka

Five modern siddhantas including S.S., and Siddhanta Tattwa-

421	viveka
449	Munjā
445	Rāj Mṛgaṅka, Karaṇa Prakāśa, Karaṇa Kutubhala etc.
444	Karaṇa Kamaḷa Mārtaṇḍa, Graha Laghava etc.
450	Bhaswati Karaṇa
438	Karaṇottama
527	Second Arya Siddhanta
532	Paraśara's view as cited in the 2nd Arya Siddhanta
342	Dāmodarīya Bhāṭaṇḍiya.

\*The information in this paragraph has been taken from Grant's History of Physical Astronomy, pp. 318-20.

\*\*The information in this para has been given on the basis of Colebrooke's essay (See Asiatic Researches, Vol. XII, p. 209 et. seq.).

\*\*\*Rehetsake observes that according to AL Butāni's opinion the equinoctial motion was 1° in 70 years (i.e. 51".4 annually). (See Journal of the Bombay B.R.A.S., Vol. XI, No. XXXII, Art III. Which of these two views should be taken as reliable ?

\* The true Aries ingress occurs 2d—10gh—15p before the mean according to S. S. and 2d—10gh—24p before mean according to Brahma Siddhanta. The difference of 2d—10gh—24p has through out been taken. It will, however, cause no difference in the result.

Original Surya Siddhanta	Five modern Siddhantas	First Arya Siddhanta	Second Arya Siddhanta	Raj Migāṅka etc.	Brahma Siddhanta
58.9	0.3	58.8	0.9	1.1	7.1
29	0	29	0	0	29
Sign	Degree	Min.			

The Sun's tropical longitude\*\*at the moment of the true Aries Ingress according to different Siddhantas was as given below : —

Mean Aries Ingress (Saka 450)	Caitra S. 14, Monday (20-3-528) (after mean sunrise at Ujjayini)	Ghati	Pala
45	45	13.5	34
46	46	38.2	36
45	45	6.2	34
47	47	13.2	36
47	47	24.6	37
52	52	10.8	41

Original Surya Siddhanta Five modern Siddhantas First Arya Siddhanta Second Arya Siddhanta Raj Mriganka, Karaṇa Kuṭubhala Brahmagupta Siddhanta	(Oo caitra S. 13, Sunday)	(On Caitra S. 11, Friday)
45	13.5	34
46	38.2	36
45	6.2	34
47	13.2	36
47	24.6	37
52	10.8	41

This shows that Brahmagupta's Samkrānti differs much from the Sayana Samkrānti, by about 54 Chaitis in Saka 450, and the year in which both the Samkrāntis would coincide comes to Saka 509 this is so because the length of the year adopted by Brahmagupta is different from that of others. The question of the length of the year has already been discussed in the course of the authors account of Brahmagupta. This point and the moments of the true Aries Ingress given above show that when the Zero-precession year was determined, it was not determined from Brahmagupta's length of the year. The Zero-precession years, that is, the years in which the moment of the true Aries Ingress of the other Siddhantas coincided with the moment of the Sayana Aries Ingress, on the basis of their respective year-measures are as follows :—

Saka	Five modern Siddhantas including S.S.	Mool Surya Siddhanta, First Arya Siddhanta	Second Arya Siddhanta, Rajmrigāṅka, etc.
450	..	.	.
451	.	.	.
449	.	.	.

This will show that, of the zero-precession years given by different works (page 215), those of Munja and Bhāswati Karāṇa are very accurate. The Saka year 444 or 445 which is now in use, is also fairly accurate.\* The reason why S.S. adopted Saka 421 as the zero-precession year, in the author's opinion, appears to be as follows :—

According to this Siddhanta, the "Aryana" completes one oscillation in 7200 years; in other words the equinox moves in one direction and returns to its place in 3600 years. It was at the initial point at the beginning of Kali-yuga. The period of 3600 years from then terminates in Saka 421; and the true Aries Ingress, according to S.S., occurred in that year only about 29 ghatis earlier than the Sayana Aries Ingress; hence, Saka 421 was adopted as the Zero-precession year. The work, Karapottama, gives 438 as the year but as the author has not seen the work he refrains from offering any comments on it; still the year is very near to the correct one. According to the method given in the Second Arya Siddhanta, the year comes to Saka 527. It has already been pointed out above that as the method of finding the ayanāmpsa is similar to that of finding the declination, the rate of precession is not always the same. The second Arya Siddhanta was written some time after Saka 527, when the ayanāmpsas obtainable from other works, those calculated by the method of the second Arya Siddhanta, and those found by observing the shadow, all the three amounted very nearly to the same quantity and the number of revolutions of the ayanā-point was determined on that basis; and \*\*this is the reason why the Siddhanta gives Saka 527 as the Zero-precession year. The same thing applies to Parāśara's view cited in the second Arya-siddhanta. Anyway, the date of zero-precession adopted in our works is beyond doubt fairly accurate. It is the opinion of some that since the junction star of Revati coincided with the equinox of Saka 496, according to the accurate modern European methods of calculation, the Zero-precession year must be Saka 496; but it is not justifiable. This question will be discussed later on.

\* It is not claimed that the above calculation of the tropical longitude of the sun is extremely accurate. If there be a variation of 1 minute of arc, the zero precession year will also vary by a year.  
 \*\* Taking this for granted, the date of the compilation of the second Aryasiddhanta comes to about Saka 900.

*How Ayanamotion and the Date of Zero-precession were Determined*

We tested the accuracy of the precessional motion and the date of Zero-precession after comparing them with the tropical longitude of the Sun found from modern European works and the rate of precession determined through accurate investigations of modern times; but we must see how our people determined these things at all. Bhaskarācārya says:—

यस्यैव त्वत् सप्तमं शतं त्रिंशद्विंशतिर्दशैव । तस्मिन् दिने  
गणितं न दृष्टी रश्मिः कायः ॥ तस्य त्वेवैषादस्य यदेतत् त्वेवैषां शतः ।  
यस्यैव त्वत् सप्तमं शतं त्रिंशद्विंशतिर्दशैव ॥ तस्मिन् दिने

प्रातिपदिक, रविक २ टीका.

The purport of these lines is that the difference between the calculated longitude of the Sun on the Vernal or Autumnal equinox day and the equinox concerned, is known as Ayanāṃśa. Bhaskarācārya further observes that the difference between the longitude of the Sun on summer or winter solstitial days calculated from Siddhanta and allied works and 3 or 9 signs also gives the ayanāṃśa. The Ayanāṃśa should, therefore, be briefly defined as the "difference between the sayana Sun and calculated Sun." The *Sūrya Siddhanta*, in the chapter on "three problems" says,

एकं दृक्त्वेत्यती त्र्यहोदयं त्रिद्वयं ॥ शतं चक्रे चलिने होतुं छायाकालं करणमात्रं ॥ ११ ।  
अतस्त्रिंशत् त्र्यहोदयं त्रिद्वयं त्रिद्वयं ॥ \*

त्रिद्वयं त्रिद्वयं.

The S. S. has, in verses 17 to 19 of the above-mentioned chapter, described the method of calculating Sun's longitude from the length of the shadow and it is indisputable that the longitude so obtained must be tropical (sayana). Hence, our works define Ayanāṃśa as the difference between the Sayana Sun and the calculated Sun. And it is evident that by following this method some time after Śaka 445, our astronomers must have found the sun's longitude several times from the shadow and thereby determined first the ayanāṃśa for the date, then the ayanamotion and from that the zero-precession year. Observation work must have been carried on for several years for this purpose. It is obvious that the longer the period of observations, the more accurate such results would be.

### ASSOCIATION OF THE JUNCTION-STAR OF REVATI WITH AYANĀṂŚA-PROBLEM

The above discussion will also show that the junction star of Revati (Zeta Piscium) has nothing to do with ayanāṃśa or ayanamotion. According to modern astronomy the length of the sidereal year is  $365^{\circ} 15' 22''$   $53^{\text{vp}} 13^{\text{vpv}}$ . If that had been the measure of the year adopted by our astronomers, then the junction star of Revati or some other star assumed to be the initial point of the zodiac, would have had some relation with the ayanamotion. In other words, if the junction star of Revati had been taken to be the initial point, then Śaka 496 would have been regarded as the zero-precession year since the equinox was conjoined with that star in Śaka 496, and ayanāṃśa would

\*The meaning of this verse has been given (page 207)

\*\*Le Vernier's Tables.

have been defined as the distance of the junction star of Revati from the equinox. But the length of our year is not equal to that mentioned above, and hence, Revati were taken as the initial point, its longitude ought to have been zero; but S. S. and Lalla do not take its longitude to be zero. Aryabhata and Varāha have not given the longitudes of junction stars at all. Brahmagupta and almost all other later astronomers except Lalla regard its longitude as zero; but their initial point was not and could never have been near the junction star of Revati. If we try to find out the year when, according to the modern S. S. the sun, at the moment of the vernal equinox, was near the junction star of Revati, it comes to Saka 177; and from that date, the position of the initial point of S. S. has been moving east of the junction star of Revati at the rate of  $8''\cdot5$  per year.\* The year in which the initial point of other works except the Brahma Siddhanta coincided with Revati and its annual rate of eastward motion, agree with those of S. S. The year in which according to Brahma Siddhanta, the sun was conjoined with the junction star of Revati at the time of the true vernal equinox, comes to Saka 598, and his initial point has been moving east of Revati at the rate of  $7''\cdot38$  per year. In short, if it be assumed that the year adopted by our astronomers was sidereal and that Revati was the initial point, the year in which the equinox coincided with Revati would be the zero-precession year, and the distance of the equinox from this star (in any subsequent year) would be the ayanamśa. Theoretically, the argument would be correct; but it is not borne out by facts. In other words, we would not get the expected results because of a different length of year adopted in our works. Again, the star which is named Zeta Piscium by European astronomers and which has been determined to be the junction star of Revati by Colebrooke and other European scholars, is a very faint star. The stars have been graded according to their importance and luminosity. Very bright stars like Spica (Citra), Arcturus (Swati), Aldebaran (Rohini) are classed as stars of the first magnitude; Uttara Anuradha and some others are of the second magnitude, Krittika & some others are of the third magnitude while Puṣya and some others are of the fourth magnitude. Revati stands between the 4th and 5th magnitude. According to some, it has even been classed as a sixth magnitude star; there are only 2 or 3 other stars out of 27 which are similar or inferior to it in magnitude. Orthodox astronomers who can point out this star in the sky would rarely be found at present. In short it is such a faint star that there is hardly any possibility of its being used for observation. It is clear from the above (page 218) quotations from S. S. & Bhāskaraśāstra that it was not used for finding the ayanamśa, and wherever methods of taking observation have been described in our works, fixed stars have very little to do with them. The method of converting a planet's place into its sayana equivalent and then observing it with relation to the equinox or the Sayana sun appears to have been considerably in use. The author will now show by an example how an error would have occurred in the result, if our astronomers had assumed some relation between Revati star and precession, that is to say, if they had adopted  $50''\cdot2$  as yearly ayanam motion, which was its displacement from the equinox in one year, and had defined "Ayanamśa as its distance from the equinox." The sun's longitude on Friday the 23rd September 1887, Aśvina S. 7, Saka 1809, at sunrise according to Grahalaṅghava, was  $5^{\circ} 7' 5' 37''$ . The ayanamśas in this year were  $22^{\circ} 45'$ . Adding these to the above value, we get  $5^{\circ} 29' 50' 37''$  as the tropical longitude of the sun. The sun thus enters Libra (sayana)

\*The mean sun moves by so much during the time difference between the length of the year of S. S. and the accurate modern value of the sidereal year.

after about 9 ghatīs after sunrise and that day ought to be taken as an equinoctial day; and the Grahāṅghava almanac has given 30 ghatīs as the length of the day on that date. For the same day, Keropant's almanac and Śāyana almanac show 30 ghatīs as the length of the day. It, therefore, shows that the length of the day given by the Grahāṅghava almanac is correct. Now, Keropant's (Pāṭwardhanī) almanac has given 18° 18' 13" as the Ayanāṁśa for the date, which is equal to the distance of Revati from the equinox. Adding this arc to the Sun's longitude as calculated from Grahāṅghava, we get 5° 25' 23' 50" as the Sun's tropical longitude. This means that the length of the day would be 30 ghatīs, 4 or 5 days after the 7th lunar day of Āśvina Suktā, which is wrong. We must, therefore, accept the view that our astronomers were quite justified in determining ayanāṁśas on the basis of the difference between the observed longitude and the calculated longitude of the Sun, and the Ayanā motion on the basis of these Ayanāṁśa figures. It would be proper to change the ayanā motion, if the length of the year is changed.

#### WHEN WAS PRECESSIONAL MOTION FINALLY DETERMINED ?

It is rather difficult to say when the ayanā motion was finally determined. The Laghumānas Karāya, written in Śaka 854, has given the ayanāṁśas of its time and also 60" as the ayanā motion; and both these figures are tolerably correct. It is therefore, beyond doubt that before Śaka 800 people had completely understood the ayanā motion. The astronomical works written before Śaka 427, such as the original S. S., the First Ārya Siddhānta & the Pāṭica Siddhāntikā do not speak of the ayanā motion at all. From this it appears that the problem of ayanā motion was not considered till Śaka 427. The modern S. S. does mention it and it has been fully discussed on page 206. Brahmagupta and Lalla who lived after the modern S. S. do not make any mention of the ayanā motion while it has been referred to in the S. S. compiled before them. This fact makes one suspect that the verses about the ayanā motion in it were interpolated later. The verses in question are given in the chapter on the three problems. As a matter of fact the numbers of the Ayanā revolutions ought to have been given along with other numbers of revolutions, in the chapter on mean motions. Again, the correction on account of ayanā ought to have been mentioned in the chapter on true places, particularly at the place where the methods for finding declination and 'cara' are described; but it is not given there. There is, however, a solitary place (verse 6) in Pāṭadhikāra, where the correction is mentioned, in addition to the chapter on three problems, nowhere else it is mentioned. Further in the Mānadhikāra, the term "Ayanā" is applied to the Sun's entry into Capricorn and Cancer. It clearly shows that these verses must have been interpolated later on, because if they are totally removed from the chapter on three problems, one would not feel any hiatus in the continuity of the text. But Bhāskara-Ārya seems to think that the Ayanācalaṇa referred to by S. S. had been expanded before the time of Brahmagupta (See page 209). As Bhāskara-Ārya lived 500 years after the date of Brahmagupta, his statement must carry more weight than the inferences of modern students living 1200 years after Brahmagupta. One is thus at liberty to say that the problem of Ayanācalaṇa must have been under consideration at the time of the modern S. S. as it existed before the time of Brahmagupta. It was, beyond doubt, discussed in Viṣṇu Candrā's works which existed before the time of Brahmagupta, about Śaka year 500. It was Brahmagupta's opinion that a Samkrāntā was Sun's entry into a tropical sign and the śāyana "Mithunānta", (the Sun's exit

from Gemini), the beginning of Dakṣiṇāyana. (This has already been shown in my account of Brahmagupta). Lalla's works make no reference to the ayanā motion. It may be due to the fact that either it was his belief that the beginning of Dakṣiṇāyana and the end of Mithuṇa sign were the same, or else, the difference between the longitude of the calculated and observed (Sāyana) place of the sun was not perceptible in his time. In short, the 'ayana calana' became a problem of study about the year Śaka 500 and that a thorough knowledge of the problem was acquired by Śaka 800.

#### CHAPTER IV

#### ON OBSERVATIONS

##### General Description

The word 'vedha' is derived from the root 'vyadha'. Vedha is the name given to the act of observing the sun or any other celestial body by holding a rod or a stick or some other object in between. Because the luminous celestial body is 'struck' by the rod, the act of observation has received the name "vedha". The simple casting of a look at a celestial body is termed 'avalokana' (sighting); but this act also can be termed 'observation'. Let us call this kind of observation 'dṛṣṭivedha' (i.e. look). The observation which is taken with the help of a stick or other means of taking observation, commonly known as 'instruments', should be termed 'yantra-vedha' (i.e. instrumental observation).

##### Our Tradition favours Observation

Europeans say that our people have no knowledge of observation, that our country lacks the tradition of taking observations, and that they have no instruments for taking them; and they put forth this plea as the main ground for their contention that the Hindus borrowed the science of astronomy from the Greeks. Certainly it cannot at all be said that our people have no liking for observing natural phenomena or that they have no such tendency. This has been proved on the basis of many things pointed out in Part One. Thus the 27 nakṣatras, were known to us even in the dim and distant past, the Vedic times. The Rīgveda refers to Saptaṛṣi stars and the planets. The Yajurveda describes the 27 nakṣatras at great length. In addition to this, the author has pointed out allusions to the constellations known as the pair of divine dogs, the divine boat, and the Prajāpati controlling the nakṣatras. The Taittirīya Saṃhitā narrates a lengthy story about the extreme love of the Moon for Rohini, and the origin of the story is found in the phenomena of the Moon's close conjunction with the star Aldebaran, and the latter's occultation by the Moon, which occurs repeatedly in a period of six years out of every nineteen. The Aśwalaśāsanasūtra allude to Dhruva and Arundhatī. We know of the phenomenon of saturn splitting the ear of Rohini 7000 years ago. The Mahābhārata abounds in the description of planets, comets and stars, and the instances have already been cited before. Even the Rāmāyana of Valmiki refers to the planets and stars at many places. Clusters of stars are mentioned in the Yajñavalkya Smṛti. Our liking for the observation of phenomena becomes evident from these several references occurring in works which are not purely astronomical. Again, there is no doubt that some at least out of the saṃhitās compiled by Cārga and others belong to a period prior to that in which our astronomical system was firmly established. They

mainly deal with the question of "grahacāra" i.e. the movements of planets through the nakṣatras. Varāha Mihira has in a long chapter entitled 'Ketu-cāra' described a good many comets. In the beginning of the chapter, he observes,

ग्राहिषं हि हिचार् पुराणैरुपदिष्टं बहुतं च ॥ अ-ग्राहिषं बहुतं, इदं हि त्र्यम्बकमुक्तं चार्ः

which means that he was describing the comets on the basis of the descriptions given by Garga, Parāśara, Asit, Deval, and many other sages. The author is giving below some of the quotations from Parāśara and others, cited by Bhaṭṭopala in his commentary on the above verse:—

पुनरुदयश्चक्रः पञ्चपञ्चादं शीघ्रं द्रिष्टः ॥ ..... अथोदयः स्वतःकुर्वन् शीघ्रं ..... पुनरुदयश्चक्रः

इत्युः ॥ ..... शीघ्रगतां विषां दक्षिणं शीघ्रगतां पश्चिमं, पुनरुदयश्चक्रः स्वतःकुर्वन् शीघ्रं द्रिष्टः ॥ ..... अथोदयः स्वतःकुर्वन् शीघ्रं ..... पुनरुदयश्चक्रः

पुनरुदयश्चक्रः स्वतःकुर्वन् शीघ्रं द्रिष्टः ॥ ..... अथोदयः स्वतःकुर्वन् शीघ्रं ..... पुनरुदयश्चक्रः स्वतःकुर्वन् शीघ्रं द्रिष्टः ॥ ..... अथोदयः स्वतःकुर्वन् शीघ्रं ..... पुनरुदयश्चक्रः

पुनरुदयः

*Purport.*—The Paṭanmaha comet re-appears after travelling for 500 years (i.e. disappears for 500 years, after it is first seen and then appears again). The comet named Uddalaka Svetaṅga appears after travelling for 110 years. The comet Kāśyapa's tail is pointed like a spear, and who, after the disappearance of the comet Padmāṅga, first appears in the East, after having travelled for 1500 years, and who, after contacting the Brahma (Abhijit) constellation, the Pole star, the Brahmaṅga\* and the Great Bear, traverses the third part of the sky, turns to the left and gives plenty of crops for as many years as the number of months it remains visible in the sky, with its semi-circular tuft of hair. Vibhāvasūjaraśmikt, after having travelled for 100 years, makes its appearance near the Kṛtikā stars after the Avartaktu. It has a tail of smoke.

Descriptions of many such comets are available. The comets may have received the names Uddalaka, Kāśyapa etc. after the Rṣis who discovered and investigated the nature of these comets. This is just like what we find at present in the case of comets such as Enke's comet, Halley's comet, etc. named after European astronomers; and these descriptions appear to have been given on the basis of researches traditionally carried on through centuries. The statements of Aryabhata and Brahmagupta that they determined the positions of the Sun and Moon after observing the eclipses have already been given. If the work of taking observations is carried on continuously for several years, it gives useful results; and it is not possible to do this without royal patronage. Varāhamihira has described how astronomers deserve respect. He has also written that kings should employ astronomers in their service, that some of them should be engaged in the task of taking daily observations of the sky, and that they should distribute amongst themselves different parts of the sky, and then take observations. From this and

\* The word Brahmaṅga occurs in Chapter III of Bhṛgusampradāya in Bhaṭṭa, as can be seen from the extract given in Part I (page 117). It seems from this and also from the above reference; as also from the fact that Brahma was the deity controlling the Abhijit star and the description of the place occupied by the comet agrees with what one may find on the celestial globe. There is nothing impossible in this; particularly the semicircular shape of the hair (described in the passage) tallies exactly with the position with respect to stars in the sky.

from the astronomical works, *Rajamṛgāṅka* Karapa by King Bhoya, and *Karapa Kamala Martapda* by King Dasabala of Vallabhā dynasty which have been mentioned before and from the fact that several authors of astronomical works had the patronage of kings, as can be seen from their own account, it appears that the work of taking observations used to be carried on by royal support. Corrections recommended by different astronomers to be applied to the mean places of planets have been given before at several places. It is evident that these could not have been devised at random. Keshava, for one has described the observations actually taken by him (page 129). *KAMALĀKARA* the author of *Siddhantatattvavivēka* has declared that the pole star has a shifting motion. Even in these days we come across persons who have a liking for observing things. One finds several persons who can correctly point out the planets and several stars even though they have not studied astronomy. Thus two persons who had absolutely no knowledge of English, Sanskrit and astronomy once casually told that the pole star is not stationary; and one of them was very fond of observing stars, risings and settings of planets and their conjunctions, and he was very helpful to the author. Once a Vaidic *Brāhmaṇa* named Pādhye, a resident of Agastī, casually met the author in Pūjā in Saka 1809. He had not studied any system of astronomy. Still, he chanced to state that, while most of the stars moved from east to west, some stars (those near the North Pole) move in a reverse direction, that is from west to east; and he told that he came to know of it from his brother *Nārāyaṇa Janardan Pādhye*. That brother died in Saka 1795. At that time he was about 22 years old. He was surprisingly intelligent. There may be several such people living. The experiences related here may appear very trivial to some; but man must have acquired knowledge of astronomy in the initial stages, through the efforts of such persons; and my object in relating such experiences is to show that the habit still persists among our people. Europeans are surprised to see that while the Saura, Arya and *Brahma siddhāntas* mention the numbers of revolutions and other elements of planets, no hint is anywhere given as to how these were calculated and no information of the observations taken has been recorded in them. But they do not take into consideration the conditions in ancient times and the beliefs of our people. In those times when even scripts or any means of writing, not to speak of the printing presses, were not easily available or were even non-existent and all knowledge was preserved by the tradition of being vocally imparted by the teacher to his disciples. Hence, it was but natural that only the *siddhāntas* which embodied the results of research survived while their sources perished. Again, nobody will now feel astonished if one predicts the time of the occurrence of an eclipse. But in ancient times a man who could predict these phenomena was naturally considered to be superhuman. If he compiled a work, he would naturally incorporate in it only the resulting principles without mentioning their preliminary forms or the means employed in arriving at them. Then in course of time, the work would possibly come to be regarded as 'apauruṣeya' (divine) after the author's name is forgotten & lost; and once this practice secured a firm footing, the future authors of 'human' works abstained from mentioning the preliminaries leading up to the final results. These were quite probably the reasons why our ancient works lack the information about the observations taken, similar to what we find recorded in Ptolemy's works about his own observations and those taken by Hipparchus, or in the works of later western astronomers. However, some information about the individual efforts made in respect of observations has already been given and some more will be given further on.

## DESCRIPTION OF INSTRUMENTS

The instruments for locating the positions of planets and those for measuring time will now be described. The works compiled by Bhāskaraśāstra are widely known. Hence, it will be of convenient first\* to describe the instruments mentioned by him and then to give a brief account of what we find in other works.

## GOLA YANTRA

OR

(Armillary Sphere)

A straight round stick of uniform thickness should be taken. It may be called "pole-stick" (dhruva-yaśi). A small spherical ball which can easily slide should be fixed in it, in the centre, to represent the earth. Then a (concentric) sphere to represent the starry sphere should be fixed all round it. It should represent the celestial sphere in which the Sun and other planets are seen to move round the earth. The construction of the starry sphere (bhagol) is as follows:—

Prepare an exactly circular ring\*. It should be so tied at two points to the pole stick that it will be divided by those points into two exact parts. A second ring of the same size should be tied to the stick, so that it will cut the stick in those two points, will be perpendicular to (the plane of) the first ring, and will itself be bisected at the two points. These circular rings are called the pair of "standard great circles". Tie a third ring to these rings at four points so that it will be at right angles to them both, and the pole stick will be its axis. This ring is termed 'Nāḍīvalaya or Viśvavṛtta'. Divide this ring into 60 equal parts to represent nādis (or ghāṭikā). A circular ring of equal circumference, called 'Kṛāntivṛtta' or the ecliptic circle should be tied to the 'equator-circle' cutting it at two points and inclined to it at an angle of 24°. The Sun moves in this circle. It should be divided into 12 equal parts to represent the signs. If the ball representing the earth be supposed to be a planet other than the sun, 'great' circular rings should be tied to the 'ecliptic-circle' at angles equal to the inclinations of the orbital planes of the planets. These also should be marked to show the signs. Then circular rings showing diurnal circles should be tied to the ecliptic circle. While tying the circular rings, care should be taken to see that a portion of the stick is kept projecting and these ends should be passed into two tubes fixed in the celestial sphere whose construction is described later on. The ends of the polestick should point to the poles of the equator, so that the north end of the stick should be found to make an angle, equal to the latitude of the place, with the

\* This description has been given from the chapters on Golabandha and Yantras (instruments). If an attempt be made to describe in detail the instruments along with an explanation of their names, such as Nāḍ valaya, and other terms, much space will be occupied, and even with all that, it is very difficult to present a description that would enable one to understand them properly without actually seeing them. Hence, only a brief description has been attempted. These however, will help even a layman to understand well the chapters on Golādhyāya and Yantrādhyāya by Bhāskaraśāstra. If all these instruments are made in the Chhatre memorial scheme, they will prove very useful at a moderate cost.

\*\* Straight, pliable, and soft bamboo have been recommended for preparing these rings. Even those made out of wire will do. These rings themselves represent circumstances of circles.

north pole of the equator lying in the celestial globe which is fixed clearly all round the 'starry sphere'; and the ends of the pole stick should be so passed into tubes that, while the 'khaḡol' (celestial sphere) would be kept fixed in position, the starry globe would freely rotate in it. The celestial globe should be so set as to envelope the starry globe. Its construction is as follows. Its circular rings should, of course, be larger in size than those of the starry globe. The ring representing the 'samavṛtta' (prime vertical) which passes through the zenith, nāḍir, and the east and west points, similarly the ring representing the meridian, as also the two other rings representing the secondary directions—all these four rings should be of the same circumference. These should be tied to one another, so that each of them would pass above and below the others. The ring representing the plane of the horizon should be tied to them all, midway between them. The north pole should be set above the horizon at an altitude equal to that of the latitude and the south pole at an equal depression below it. Prepare a ring representing the 'Umāṇḍal' (six o'clock circle) i.e. the great circle which would pass through the east-west points and both the poles which are points in the meridian circle to which the ends of the pole stick in the starry globe are directed. Then tie a 'nāḍivalaya' (celestial-equator-circle) which lies in the plane of the equator of the starry globe and which is larger in size. This should be graduated into ghatis. Then fixing nails at the points representing zenith and nāḍir, another ring should be so fixed in position that it would be free to rotate in a vertical plane with the two nails as the pivots. This is to be called a 'dīṅmāṇḍal' (i.e. the vertical circle for observation). As this is to be rotated inside the celestial globe it should be somewhat smaller in size. A planet is to be observed after so rotating the vertical circle that the planet would be seen in the plane of the observation circle. This celestial globe should be so fitted around the 'starry globe' that the ends of the pole stick could be made to pass through the two tubes fitted on to it. Then after fixing two tubes in the 'khaḡol' from the outside, another globe called dīṅgola should be fitted on; and all circular rings like those in the 'khaḡol' and 'bhagol' should be fixed on to it. This globe is to be constructed so as to enable one to have a proper understanding of the actual lines like 'agra' (amplitude) 'kujya' (the radius of the earth) etc., which require the reference to two globes. The whole structure is now called a 'gola' (i.e. a globe). (Our astronomers sometimes used the term 'kṣētra', to denote lines.)

The orbits of planets should, if necessary be tied in this globe separately with circles of aphelia and perihelia. This globe has been described to show the construction of the Universe. In fact it is very difficult to tie together all these rings, and it is still more difficult to take observations with their help. For instance, if the starry globe is fixed inside a 'khaḡola', it will be difficult to fix the observation circle. It cannot be believed that Bhāskaraṭācārya and others could not realize these difficulties. It is clear that at the time of taking actual observations only the most necessary rings should be made use of, and observation can thus be taken. We had no instrument of the type of astrolabe designed by *Hipparchus*; but this speaks for the independence of our works in this respect. The above globe can be used in place of the astrolabe, *Brahmagupta*, *Lalla*, and both the *Aryabhaṭas* have recommended the construction of the same kind of globe. The globe described by the First *Ārya-bhaṭa* is less complicated than this.

Bhāskaraṭācārya has mainly described nine kinds of instruments, and their chief use is to find time; but three of them can be used mainly for taking observations of the celestial bodies. I shall here describe all of them briefly.

1. *The Cakra Yantra* (The disc instrument):—Procure a disc\* of metal or wood. Make a fine hole at its centre. Provide some pivot to the rim of the disc, to which a chain etc. can be attached to support the instrument with. Mark on the disc a line passing through the pivot and the central hole: (this will always remain vertical when the instrument is held suspended in position). Mark on it another line perpendicular to the first line and passing through the centre. Mark graduation lines on the circumference of the disc to indicate degrees. Pass a rod through the hole, perpendicular to the disc. It will serve as an axis. Hold (in hanging position) the disc, with the help of the support before the Sun in a vertical plane, so that the axis will cast a shadow on the disc. The degrees counted from the point in which the shadow cuts the rim to the point in which the horizontal line cuts it, will give the altitude of the sun, and the degrees counted from the point to the lowermost point of the disc, will give the zenith distance. (The time of the day can be calculated from this). The same disc may be so held that any two of the 'zero-latitude' stars, Rusa, Magha, Sataatara and Revati will be found to be in the plane of the rim. (The disc will thus be held in the plane of the ecliptic). Then the planet will be sighted by moving the eye to and fro, so that the axis would intercept the sight; the longitude and latitude of the planet can thus be found. It is in a way similar to the 'dīnāṅgaḥ' of the Gola Yantra.

2. *The Cāpa* (Semi circular disc):—

The half part of the Disc instrument is called a 'Cāpa' instrument.

3. *Turyagola* (Turya Yantra):—Half part of the 'Cāpa' instrument i.e. a 'quadrant' forms a Turya instrument.

These three instruments are chiefly used in taking observations.

4. *The Gola instrument* (Globe instrument):—Placing a 'bhagola' in a 'khagola', mark a spot on the ecliptic ring at a place where the sun is expected to be on a particular day. Then so rotate the 'bhagola' that the mark will cut the horizontal circle. Mark that point in the horizon in which the plane of the equator in the 'bhagola' will appear to cut. Then again rotate the 'bhagola' so that the spot marking the Sun's position will cast a shadow on the 'bhagola', i.e., the terrestrial globe. Where the shadow is cast, the number of ghatis indicated between the spot and the 'nādivālaya' will give the number of ghatis elapsed after sunrise on that day. Then the point of the ecliptic in contact with the horizon will give the ascendant at the moment.

5. *The Nādivālaya*:—Procure a circular disc. Graduate its rim in ghaticas. Pass a rod through its centre perpendicular to the disc. When the rod is held, pointed to the pole, it will cast a shadow on the rim; and from it the hour angle (natakā) or its complement can be read. If this very disc is so fitted in a globe that the pole stick will pass through its centre and the terrestrial globe will occupy the central position in it, and if marks indicating ghaticas, rising of signs, and the sixfold division of signs (Jagna; hora; dreṣṭakā; navamṣa; dvādaśamṣa & trimṣaṣa) are made on it, then the shadow cast by the stick will help in finding the time elapsed and the sixfold divisions.

6. *The Ghatikā Instrument*:—This is too well known.

7. *The Sanku* (Gnomon):—

Sanku is a piece of a round, straight and uniformly thick rod 12 'angulis' in length and having its ends plane and uniform. The chapter on three problems describes methods of finding time etc. from the shadow cast by it.

\*The description will show that it is not a wheel but a disc cut out from a sheet (of metal).

8. *The Phalak Instrument*:—It is an instrument for finding time designed by Bhāskaraśāstra on the principles of the Cakra Yantra. Its details are not given here for want of space.

#### 9. *Yasṭi Yantra* (Pole instrument):—

Draw a circle with any radius on an even horizontal ground. Mark off principal directions on it and then draw arcs showing 'agra' (amplitude of the day), both in the East and the West. Draw another concentric circle smaller in size and having a radius equal to "dyujya" (sky-radius). Mark off points on it to show 60 ghatas. Take a stick equal in length to the radius of the outer-circle and hold it pointing to the Sun, with its one end placed at the centre of the circle, so that the stick will cast no shadow. Place in the smaller circle a rod which is equal in length to the distance of the other end of the stick and the end of the amplitude marked in the east. The arc showing ghatas intercepted between the ends of the stick will show the time elapsed (in ghatas). If the sun is in the West, the distance between the ends will give the number of ghatas showing the time left for the day to end. The methods of finding a number of things like 'palabha', with the help of the 'Yasṭiyantra' have been described. Brahmagupta and Lalla have described the method of finding the distance between the Sun and the Moon, and from that the tithi, with the help of a similar but somewhat different type of a 'yasṭiyantra'.

Bhāskaraśāstra has mentioned two other additional self propelled instruments for finding time.

We find in Atharva Jyotiṣa, discussion of the shadow cast by a gnomon, which proves\* that the gnomon was known to us before our science of astronomy came in contact with that of the Westerners. The Pañca Siddhantika contains a chapter on instruments, which is not quite intelligible; still it appears that many of the instruments described by Brahmagupta and others were in use in those times. Aryabhata I has not described any instruments at all, but has mentioned a globe as described above. He has, in addition, stated that a globe should be so prepared for finding time that it will automatically rotate with the help of mercury, oil, or water.\* Take a wheel. Fix in it somewhat hollow spokes half filled with mercury, with their ends sealed. The wheel will then rotate automatically. Brahmagupta and Bhāskaraśāstra have mentioned one such automatic instrument. From the globe instrument of Aryabhata described above and from the references in the Pañca Siddhantika to some wonders occurring automatically by means of the instruments, it appears that at the time of Varāhamihira there existed such instruments and some other kinds of 'wayam waha' i.e., automatically working instruments. Varāhamihira and Aryabhata have not described the process of construction. Brahmagupta also has described, in addition to the above instruments, some other wonders happening automatically, but has not described their processes. Instruments of the same type or with certain variations as those described by Bhāskaraśāstra are met with in the works of *Brahmagupta* and *Lalla*.\*\*\* But both of them have mentioned some additional instruments for finding time,

\*(3) Atharva Jyotiṣa",

\*\*Aryabhata, Golapida, couplet No. 22.

\*\*\*Bhāskaraśāstra invented a new instrument called the Phalak instrument; but its origin is to be found in the Cakrayantra itself. Out of the remaining eight, Brahmagupta has not explicitly mentioned the Gola & Nāḍivalaya as separate instruments. He has, however, mentioned the Golabandha which includes the two. Lalla has not mentioned the Nāḍi-valaya out of the eight instruments, but it is included in the Gola itself. It is, however, somewhat surprising that he has not mentioned the Turīya instrument.

viz. Kartari, Kapāla and Pīṭha. The modern S. S. does not describe any instruments in detail; still it has mentioned the names of the following instruments:—Swayam-waha, Gola, Saṅku, Yaṣi, Dhanu, Cakra and Kapāla. It is interesting to note that the Pañca Siddhāntikā, Aryabhatīya, modern S.S. and Lalla-tantra do not anywhere mention the 'Turiya yantra'.\* It was Ptolemy among western astronomers who first invented the quadrant instrument. Before his time, they used the complete circular instrument for taking observations; but later on, the Western astronomers began to use the quadrant instrument for all purposes. In modern times, however, the quadrant instrument has completely disappeared and the complete circle instruments have come into use in their place. Modern scholars accuse Ptolemy of having taken a retrograde step by introducing the quadrant instrument.\*\* The purpose of mentioning this here is that while the quadrant instrument has been mentioned by Ptolemy, it was not known to our astronomers till Śaka 500. It, therefore, proves that the Romaka Siddhānta is neither a translation of Ptolemy's work nor has it been compiled on the basis of that work and that we knew nothing about Ptolemy's work, till at least Śaka 500. The same thing was seen before from our study of the Romaka Siddhānta (Page 12). One more important thing which comes to our notice is that all our instruments have been invented by our astronomers quite independently; and the quadrant instrument which came into use later on, was also independently invented. It could have been easily suggested by the 'cakra' and 'cāpa' instruments; and since it occurs for the first time in Brahmagupta's work, it must have been invented by him.\*\*

The second Aryasiddhānta and modern Siddhāntas by Romaka, Śakalya, Brahma, and Soma do not contain the chapter on instruments at all.\*\*\*

## ANCIENT OBSERVATIONS OF WESTERNERS

It would not be irrelevant to say something here about the ancient methods of observations of the Westerners.† The Chaldeans, to whom the origin of astronomy is usually ascribed by European scholars, do not seem to have attained any excellence in this important department of the science. Their observations of eclipses of the moon, as cited by Ptolemy†† are as rude as can possibly be imagined. The time is expressed only in hours, and the quantity eclipsed in terms of the half & quarter of the moon's diameter. Herodotus states that the Greeks were indebted to the Babylonians for the pole, the *gnomon* and the division of the day into twelve hours. The pole seems to have been \*After detecting this omission, the author could not find time for reading the texts of these works minutely, particularly with an eye to the word "turiya". I have, however, gone through all those portions of the works where that word could possibly have occurred and ascertained that it does not occur there.

\*\*Grant's *History of Physical Astronomy*, p. 440.

\*\*\*The fact that no mention of the 'turiya' instrument has been made in the *Sūrya Siddhānta* is an additional proof to show that the work was compiled before Brahmagupta's

\*\*\*\*That does not, however, prove that these Siddhāntas were compiled earlier than the *Sūrya* and other Siddhāntas.

†This paragraph has been written on the basis of Grant's *History of Physical Astronomy*, Chapter XVIII.

††Rebhatasik states that the most ancient of these observations are the three eclipses which occurred in the years 719 and 720 B.C. (Journ. B.B.R.A.S. Vol. XI).

a concave hemispherical sun-dial, having a vertical style in the centre, by means of which the interval included between sunrise & sunset was divided into twelve equal parts. It is probable that by the use of the gnomon the Chaldeans succeeded in obtaining an approximation to the length of the solar year, but there is not the smallest reason to suppose that they employed it in determining any other of the fundamental facts of astronomy. Indeed, they do not seem to have made observations at all for the purpose of forming materials to serve as the groundwork of future reasoning. They simply contented themselves with noting the more remarkable phenomena as they occurred, and hence deducing a few rough conclusions of a general nature. It would appear, however, that by comparing together the Chaldean records of eclipses some of the Greek mathematicians ascertained with considerable accuracy several periods relating to the motion of the moon. The earliest astronomical observation recorded as having been made by the Greeks previous to the establishment of the *Alexandrian school*, is a determination of the summer solstice by Meton, in the year 430 A.C. The instrument, termed a heliometer, which was used by Meton on this occasion was, in all probability, no other than a modification of the gnomon. The date of this solstice has been chosen for the epoch of the Metonic cycle of nineteen years.\* A new era commenced in the history of astronomical observation when *Alexandria* became the capital of the civilized world. Under the liberal patronage of the Ptolemies a magnificent building was erected, in which were deposited circular instruments for determining the positions of the heavenly bodies, and every facility was given to astronomers for prosecuting a continuous series of observations. Timon-charis and Aristillus are the earliest individuals mentioned in connexion with this school. These astronomers appear to have flourished about the year 300 A.C. *Ptolemy* (150 A.D.) cites several of their observations. Among these are the declinations of a few of the principal stars and the records of eclipses. It does not appear that they were acquainted with any method for determining the right ascensions of the stars. Eratosthenes (275 B.C. circa) one of the Alexandrian astronomers, determined the obliquity of the ecliptic to be  $23^{\circ} 51' 19''$ . It is manifest that neither the distances of the stars from the equator nor the obliquity of the ecliptic could have been determined even roughly without the use of instruments. In treating of the obliquity of the ecliptic, Ptolemy describes an instrument for determining the meridional altitude of the sun. It was composed of two concentric circles, placed exactly in the plane of the meridian, one of which revolved within the other about their common centre. The inner circle carried two small prisms attached to the opposite extremities of a diameter, and when the sun was on the meridian, it was turned round until the shadow of the upper prism fell exactly upon the lower one. An index, affixed to the latter, then marked upon the graduated limb of the outer circle the meridional altitude of the sun. It was, in all probability, by means of an instrument of this construction that Eratosthenes determined the altitude of the sun at each of the solstices & hence deduced the obliquity of the ecliptic. Ptolemy cites a passage from Hipparchus which shows that at Alexandria they used to ascertain the passage of the sun through the equinox by means of a circular ring of metal disposed in the plane of the equator—the shadow of the upper half being watched until it fell upon the inner or concave surface of the lower half. It is not by what means the earlier astronomers

\*Meton fixed 6940 as the number of days in a cycle of 19 solar years (Indian Era by Cunningham, page 43). This makes the length of the year 365d 15gh 47 368pr. Calippus made an improvement in the Metonic cycle by discovering the cycle of 76 years by which the length of the year became exactly 365d—15gh (Indian Era, p. 43). It is worth noting that none of our astronomical works have adopted these cycles or lengths of year.

determined the declinations of stars. Whatever credit may be due to the earlier astronomers of the Alexandrian school for the sound principles of observation which they appear to have practised, it is to Hipparchus alone that the establishment of astronomy, as a science of calculation based upon observed facts, is to be attributed. He determined the length of the year to be—365d—14g—48p as against the former measure of 365d—15g. He invented the astrolabe with which he used to find the longitudes and latitudes of celestial bodies. No one before him had a correct knowledge of the sun's apparent motion; and it was he who first compiled tables for calculating sun's true place; these were not known to anyone before him. He recorded observations of the moon, and appears to have compiled tables for finding the true place of the moon. He recorded observations of planets also. The observations recorded by Hipparchus proved useful to Ptolemy in deducing the correction for moon's longitude, called "evection" and to establish the rule for finding the planetary motions. It has already been stated that Hipparchus found the longitudes and latitudes of stars. Ptolemy was not skilled in the work of taking observations. He invented the quadrant instrument. It is nowhere mentioned in clear terms how all these astronomers used to find time. It appears that they used to measure time by the shadow instrument and the clepsydra ('ghatī' instrument). Sometimes they used to record what part of the ecliptic was transiting the meridian at the time of taking observations. The Arabs did not bring about any appreciable improvement in the instruments of observation; however, their instruments of observation used to be larger and better than those of the Greeks. The astrolabe used by them was much more complicated.

The above account will show that none of the various legends of the years described so far agrees with those established by our siddhāntas. It has been proved in the study of the five ancient siddhāntas, that though the original Romakasīdhdhānta may have been compiled on the basis of the work of Hipparchus, the Romaka was not the most ancient of our works and that there were works on mathematical astronomy even before the Romaka (page 2).—

Now the author will describe our independent works relating to instruments and observatories:—

**SARVATOBHADRA YANTRA**:—It appears from two verses quoted by Bhāskaraçārya, as from this work, in the chapter on instruments in the Siddhānta Siromani, that he wrote a work of this name for describing instruments, but as the work is not available, it cannot be described how the instrument was constructed.

**YANTRA RĀJĀ**:—There lived in Bhṛgupura an astronomer Madan Sūri by name. His disciple Mahendra Sūri compiled this work in Saka 1292. There is at the beginning of the work a salutation to 'sarvaṇa' (i.e. the knower of all things). From this it appears that this writer must have been a Jain. The work consists of five chapters viz. Gaṇita (mathematics), Yantraghaṭanā (principles of instrument making), Yānta rācanā (construction of instruments), Yāntarasādhana (use of instrument), Yānta vicāraṇa (theory of instruments), and has in all 182 verses in it. MAṬAYENDU SŪRI has written a commentary on it, in which he says that Mahendra Sūri was the Head Astronomer at the Royal Court of Emperor FERUZ SHAH. The Samvat 1435 (Saka 1300) has been adopted in many of the solved examples. In one case the Samvat 1427

has been taken and in another, Samvat 1447; and the commentator calls *Mahendra Suri* his preceptor. This shows that he (Malayendu Suri) was his direct disciple; and the date of compilation of the commentary also was about Saka 1300. Sudhākara Dvivedi published this work at Vārāṇasi. The author observes in the very first chapter,

एतन्मन्त्रं ब्रह्मणोः प्रवृत्तं यन्मन्त्रं प्रवृत्तं ॥

नामं ब्रह्मणोः प्रवृत्तं यन्मन्त्रं प्रवृत्तं ॥

अथवा ?

"The writer is presenting in this work the description of instruments which he has gleaned from various works on instruments written by Yavanas, just as nectar is taken out from ocean."

He has assumed 3600 as the radius and  $23^{\circ} 35'$  as the maximum declination; he has given tables of sines, declinations and sky diameters for each degree and has given the length of the shadow cast by a gnomon of seven inches for each degree of altitude, varying from  $0^{\circ}$  to  $90^{\circ}$ . The commentator has given the latitudes of about 75 cities. The author of the work has given sayana longitudes and latitudes of 32 stars which are useful for observation, and has mentioned  $54'$  per year as the precessional motion. It is not possible to describe the construction of the instrument, Yāntra Rāja, briefly, and hence it is not given here. With the help of this instrument the following things can be found directly from observation:—the altitude, zenith distance, longitude and latitude of the Sun; planets and stars; distance in degrees between any two celestial bodies, the latitude of a place, the ascending sign and the time and length of the day. There is a commentary on this work written by Yajñeśwara in Saka 1764.

*DHRUVA-BHRAMA-YANTRA*:—PADMANĀBHA, son of Narmada compiled this work. It has already been pointed out (page 126) that the date of this Padmanābha is about Saka 1320. The work consists of 31 verses and has a commentary written by the author himself. This instrument known as Dhruvabhrama Yāntra is meant to find time and it consists of a rectangular plank of wood, the length of which is double the width, and which has a chinik bored in it parallel to the shorter edge, the constellation of Dhruva-matsya (polar fish) is to be observed through the chinik. The author does not intend to describe here in detail the construction of the instrument meant for finding time. The author has described the "Polar fish" in the following words:—"There is a cluster of 12 stars round the North Pole. It is called the 'polar fish'. It has two bright stars, one of which is regarded as its mouth and the other as its tail. One of these is on one side of the pole at a distance of  $3^{\circ}$  and the other lies at a distance of  $13^{\circ}$  on the other side." The author has described the construction of an instrument by which time can be noted at night by observing the stars situated at the mouth and the tail. A method has been described for finding time by observing other stars at night and even the Sun during the day. Similarly, even the ascendant at any moment is found with the help of this instrument, and it evidently gives the sayana ascendant. The mean altitudes of junction stars of 28 asterisms at transit as observed in latitude  $24^{\circ}$  N have been mentioned. It shows that the author may have been the resident of a place whose latitude is  $24^{\circ}$ .

\*See commentary on the 11th verse.

A mathematician named *Cakradhara*, son of *Vamana*, compiled this work and it has a commentary written by the author himself. In addition to this, there is a commentary on the work by *Rāma*, son of *Madhusūdana*, a resident of *Parthapura*. The author has not given his date, but as he has quoted in his commentary some lines from *Bhāskara's* *Siddhanta Śiromaṇi*, and *Rāma*, the commentator, has mentioned *Saka 1547* as the date of his commentary, the work must have been written some time between *Saka 1100* and *1500*. His words, "ksitipalamaulivilasadratna grahajñyāgrahī cakradharaḥ" mean- ing, "Cakradhara, the leading astronomer, and who is a jewel in the crown of kings" shows that he had the patronage of some king. The work has four chapters containing 26 verses in all. *Uinakara*, son of *Ananta* belonging to *śaṅḍīya* gotra wrote a commentary on it with examples in the *Saka* year 1767. *Yantracintamani* is a kind of quadrant instrument. The observations taken with this instrument give the longitudes of the Sun and the Moon, and also the longitudes and latitudes of five planets, the desired time, and the ascendant true for that moment, and such other things. The planetary positions and the ascendant are *sāyana*.

Gaṇeśa Daivañja, the author of the *Grahaṭāṅghava*, compiled this work on instruments. It contains 13 chapters. The author claims that even while riding a horse one can find time by observation with the help of this Pratoda yantra, and also the shadow cast by the gnomon at that time. Its construction is not described here for want of space. Sakharāma and Gopinātha have written commentaries on this work.

This instrument was invented by Cīntāmaṇi Dīkṣit (page 174). He has written a work entitled *Golāṇḍa* concerning the instrument. It contains 124 verses. It has chapters (*adhikāra*) on the construction of the instrument, mean places, true places, three problems, eclipses, shadow, risings and settings of planets, observations and conjunctions. The following things can be found from observations taken by the Golāṇḍa instrument:—Equation of centre to be applied to planets, planet's distance from the earth, true motion, declinations, ascensional difference, ascendant, directions, amplitude, zenith distance, *valan* (deflections), parallax, *naṭi* (parallax in latitude), latitude, *dikkama* and the desired time. There is a commentary on the work entitled *Golāṇḍanubhāṣikā* by Yaśeśwara.

॥ भवः क्षीयति सर्वथा सर्वत्र ॥

"I have seen almost all instruments prepared by learned men, and it is my belief that this 'yantracinidamani' is the best of all." This shows that several kinds of instruments were in use.

The instruments described in Siddhantasiromani and other independent instruments mentioned above are rarely seen constructed by any one at present. The gnomon and the quadrant instrument are found at some places. Some instrument by which the time of the day can be found is seen at a number of places.\*

## OBSERVATORIES

Let us now consider the question of observatories. It is evident that if the instruments of observation are permanently fixed they will be found more useful for observation. A building is specially erected for this purpose, and instruments are fixed in it and the work of taking observations is carried on there. Such a place is called '*Vedhasala*' (or Observatory). It seems probable that in ancient times in our country such places might have been built under royal patronage and reserved for this purpose; but we do not anywhere find their description. In some places, stone slabs are found on which lines showing directions are marked. It has been mentioned before, that Cintamani Dikshit had such an arrangement for showing directions made at his place of residence in Satara. In 1884, the author had gone to Indore for taking part in the Sayana pancāṅga controversy. There he learnt that a place had been purposely set apart in the palace area, where lines showing directions have been marked, and astronomers, engaged by the Maharaja Tukoji Rao, sometimes used to take observations there. The author met an astronomer from Bid who told him that some years ago some instruments had been constructed for the purpose of carrying on the work of taking continuous observations with the help of a party of astronomers maintained by the Moghul Government at Hyderabad; but the work was later on discontinued. The author has seen astronomers at times taking observations by means of tube instruments. Such attempts on a moderate scale must have always been made in the past, but we have at present a reliable information about only one attempt of this kind made on a very big scale. It is as follows:—Jaya Simha (page 169) built five observatories. The author is giving below, an extract\* from the introduction to his own works

\*While this chapter was being printed (during the months of Vaisākha and Jyestha of Saka 1818) Mr. Narasimha Ganēśa Bhanu, a resident of Miraj, sent to the author some papers on which he had copied out diagrams of some of the instruments. Bhanu is not an astronomer. He is at present a pensioner of the Miraj State, still, he has a great liking for this subject. The original instruments of which these were the copies were constructed by one Sakharama Joshi, a resident of Kogoli near Kolhapur, between Saka 1712 and 1718. Of these, some were probably made of cast brass, as stated by Bhanu. They include *grades of some instruments* and '*turya yantra*', '*phalak yantra*', '*dhruvabhramana yantra*' and other instruments. One kind of '*Yantraj*' instrument was constructed at Saptarsi (Satara) in Saka 1712; it has marked on its dial  $17^{\circ} 42'$  as the latitude of Satara, and the altitudes of junction stars of 27 asterisms and of some other stars at the times of transit, along with their directions; e.g. the altitude of Magha has been given as  $83^{\circ} 57'$  South. Another '*Yantraj*' has been constructed for Karavir (or Kogoli) in Saka 1718. It has marked on it  $17^{\circ} 21'$  as the latitude of Karavir (Kogoli) and the altitude of Magha as  $84^{\circ} 15'$  South. According to modern astronomy, the latitude of Satara is  $17^{\circ} 41'$  and that of Kolhapur  $16^{\circ} 41'$ , and the Saka 1718, the declination of the junction star of Magha was about  $12^{\circ}$  North; and the transit altitudes of the star were  $84^{\circ} 19'$  at Satara and  $85^{\circ} 19'$  at Kolhapur. Anyway, Sakharama Joshi appears to have been very painstaking. The above-mentioned instruments are at present with his great grandson Sakharama Sasiri at Kadeguddi near Belgum in the Sahapur Taluka. His another great grandson Mornasiri lives at Miraj, and he has also some instruments with him.

\*This extract has been taken from an article by the well known scholar, William Hunter, published in Asiatic Researches, Vol. V, pp. 177-211.

**KSIZ MOHOMED** by name. It will give a complete idia about his efforts :—  
 The theorems of Euclid are but an imperfect form of divine work. Similar by thousands of people like Jamshedkasi and Nasirusi, have laboured in vain and became fatigued. The calculations made from works on astronomy like those of Sayad Gurgani and Khayani, the Akbarshahi work of Insi-al-Mulacand and astronomical works of Hindu writers as also those of European writers, do not agree with observed phenomena ; especially, the new moon's appearance, risings and settings of planets, eclipses and conjunctions of planets do not agree with observation at all. When this fact was told to Emperor Mohomadshahi, he asked him (i.e. Jaya Sinha) to decide the matter. He erected at Delhi instruments like those erected by Mirza Ulugbeg at Samarkand..... Jaya Sinha found that his ideas about the correctness of results could not be realized by brass instruments, because the instruments were small, not convenient for showing minutes of arc, their axes shift their places and get worn out ; the centres of circular plates also shift their places and the planes of instruments get twisted. He thought these to be the reasons why the calculations of Hipparchus and Ptolemy did not tally with observed results. He, therefore, erected the Jaya Prakash, the Rama, and the Samrat instruments which were perfectly stable and built in mortar and stone, whose semi-diameters were 18 cubits, and one grain (gava) in the circumference of which would represent 1 minute of arc. These were constructed and erected with due consideration of geometrical theory, the meridian, and latitude of the place and with careful measurements. They were so designed that it would be possible to repair the defects caused by the sinking of circular plates, veering out of axes, shifting of the central points, and irregular spacing of minute divisions. An observatory of this type was built at Delhi. Corrections to be applied to mean motions of planets, which never agreed with observation, were finally determined on the basis of observations taken with these instruments. In order to test the correctness of results of observations taken at the Delhi observatory, he erected similar observatories at Sawai, Jaipur, Mathura, Varanasi and Ujjayini. Observations taken at all these places tallied with one another. After seven years were spent in taking these observations, it was learnt that similar work was being done in Europe also. Hence, MANUEL, the priest and some other scholars were sent there and the planetary tables compiled 30 years ago and published in the name of *LIEU*, were brought through them. The calculations made from them, however, did not agree with observations; it was found that there was an error of about 1/2 degree and some perceptible error in the case of other planets. Hence, under the direction of the Emperor, a work was compiled containing formulae and mathematical processes for calculation, which were very precise and correct. Its calculation exactly tallies with observation. (The emperor's name was given to the work as a mark of honour.)

**HUNTER**, visited four out of the five observatories about the year 1799 A. D. and wrote their description in the "Asiatic Researches" mentioned above. It is not given in full for want of space. The description of the observatory at Varanasi, as given by Sherring (1868 A. D.) in his English book

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He was on the throne at Delhi from 1720 to 1748 A. D.

\*Jaya Sinha completed the compilation of his work in 1141 Hijri era (i.e. 1728 A.D. or Saka 1650). The work brought from Europe was of De Levartior. It was first published in 1678 A. D. and then again in 1702 A. D.



## (2) ADHIKĀRA ON TRUE PLACES

## Chapter I

*True places and motions of planets*

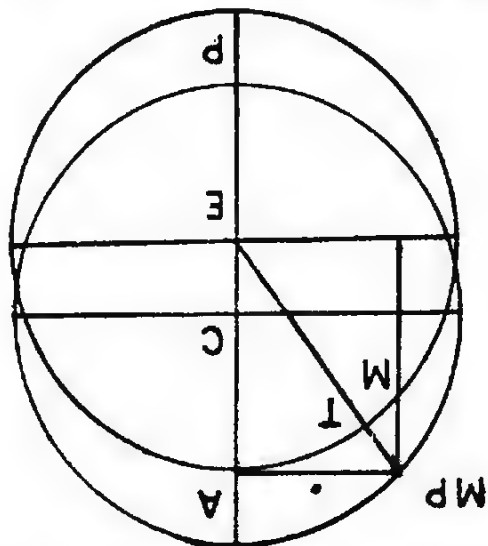
A planet is not found moving every day at its mean daily rate of motion which is obtained from the time it takes to make a complete revolution through the Zodiac, but at a greater or smaller rate; and hence, on a given day it is not seen actually occupying the place in the sky which is found from its mean motion by calculation. The position and motion of a planet as actually seen in the sky are called its true (spāṣṭa) place and motion. It is the subject of study for the chapter on true places to find the true position and motion of a planet from its calculated mean position and motion. [It is a convention with our works to speak of the true position of a planet as "true planet" (spāṣṭa graha) and hence, this term is so used in some places in the following discussion.]

The chief reason why the true motions of the Sun and Moon differ from their mean motions is that according to the laws of planetary motions, which are now almost universally recognized, and which were first discovered by *Copernicus*, and verified and firmly established by *Kepler* and *Newton*, the earth revolves round the Sun, and the Moon round the earth in an elliptical orbit; and there are two reasons why the true motions the remaining five planets differ from their mean motions; Mercury and the other four planets revolve round the Sun in an elliptical path, which gives them in their orbits a position different from their mean positions and the other reason is that this position of planets relative to the Sun, appears still different to us (observers on the earth), since the earth constantly changes its position in the sky while revolving round the Sun.

Although our ancient astronomers did not know these reasons in their real perspective—two reasons in the case of five planets and one in the case of the Sun and Moon, they have unknowingly assumed the same principles to start with, while finding the places of planets; and the true positions of planets which we obtain by following our works agree to a considerable extent, if not to the fullest extent, with those obtained by following the methods which the Westerners have established after understanding the theory. In other words, the mean position of a planet being the same, if it be found by Western methods of calculation occupying a particular place in the sky, we too get the same or very nearly the same place by following our own works; and the difference, if any, in the two results is due to some slight defects or approximations of the elements assumed in our calculations, and also to the fact that some other elements, in addition to the above two reasons, which have been lately discovered, were not known to our people. The following discussion will confirm the truth of the above statement that the two main reasons were indirectly known to our astronomers.

The theory underlying the method of calculating the true place of a planet from its mean place is explained in our works by means of a diagram. Here the theory is given, as it will help one to understand what the reasons are which cause a difference between the true and the mean place of a planet, and what the ideas of our astronomers were regarding this question. They draw

to occupy would be said to be its true place.



at 1, and the true planet appears

The orbit circle drawn in the operation of "manda karma" becomes the "sighra-pravritta" in the operation of "sighra-karma", then taking a point away from the centre of this circle, at a distance equal to the sine of the maximum value of "sighraphala", another orbit circle is drawn with this point as centre.

The earth itself is supposed to be at the centre of this orbit circle drawn in the operation of 'śighra-karma'. The place where the heliocentric planet, while moving at its own rate of motion in the "śighra-prati-vṛta", appears to be in the "śighra-kakṣāvṛta" is its geocentric position. The planet appears to be in that place to an observer on the earth. Some people treat the "mandakakṣāvṛta" itself as the "śighra-kakṣāvṛta", and then they draw an equal circle called the "śighra prativṛta", having for its centre a point which is marked at a distance equal to the sine of 'śighraṇṭya-phala' from the original centre. Then the heliocentric position of the planet from the 'mandakakṣāvṛta' is transferred to the "śighra-prativṛta", and its place as seen in the "kakṣāvṛta" is taken to be its geocentric position. Both the methods lead to the same result.

The above diagram will show that the distance of the planet moving in the eccentric circle is not the same from the point E. The distance is greatest when the planet is at A (aphelion) and the least when it is at P (perihelion); in other words, the path of the moving planet is as it were assumed to be, elliptical. E is one focus of this ellipse.

Parameśwara, the commentator of Aryabhaṭa, has described in simple words, the method of drawing the figure for finding the equation of centre. The author has not come across an equally good explanation in any other work. The author, therefore, quotes the verses here :—

विष्याकृतं कृमय कक्षावृत्तं भवेत् त्वच्छिष्य ॥

शीघ्रादिषु तस्य कक्षावृत्तं शीघ्राद्यकलावृत्तं पुनः कर्त्तुं ॥ २ ॥

कृत्वा विनिवृत्तं वृत्तं शीघ्रप्रतिमन्त्रलक्ष्यमपि विनिवृत्तं ॥

इदमेव भवेन्मादं कक्षावृत्तं पुनस्तु तत्कक्षावृत्तं ॥ ३ ॥

कर्त्तुं कृत्वा मन्दलियकलावृत्तं वृत्तमपि च मन्दलिषु ॥

कृत्वा शीघ्रप्रतिमन्त्रलक्ष्यमपि विनिवृत्तं मन्द शीघ्राद्यमप्युपजाः ॥ ४ ॥

मन्दप्रतिमन्त्रलक्ष्यमपि विनिवृत्तं कक्षावृत्तं त्वं भवेत् ॥

तत्र हि तेषां मन्दकृत्तः प्रदिष्टास्तथैव शीघ्रे तेषां ॥ ५ ॥

प्रतिमन्त्रलक्ष्यं विनिवृत्तं त्वं भवेत् पुनस्तु शीघ्राद्य ॥

कक्षावृत्तं प्रतिमन्त्रं भागं तत्र स्फुटयद्वास्तु स्युः ॥ ६ ॥

मादं कक्षावृत्तं प्रथमं वृषाक्षयः कृमय स्यात् ॥

तत्कक्षावृत्तमपि मन्दलियकलावृत्तं त्वं भवेत् स्यात् ॥ ७ ॥

मन्दप्रतिमन्त्रलक्ष्यं प्रतिमन्त्रं भवेत् विनिवृत्तं शीघ्राद्य ॥

प्रतिमन्त्रलक्ष्यं भवेत् शीघ्राद्य तस्य मानमपि च गतिवृत्तं ॥ ८ ॥

शीघ्राद्यवृत्तलक्ष्यं प्रतिमन्त्रलक्ष्यं भवेत् शीघ्राद्य ॥

"The orbit circle, at the centre of which is the earth, and whose radius is equal to 'trijā' is called a 'śaighra' circle (i.e. the orbit circle necessary in the geo-

"The word 'trijā' is now-a-days used as a technical term signifying semi-diameter. But originally it stood for 'jā' (size) of 'tribha' (i.e. 3 signs or 90 degrees); and our astronomical works are generally found using it in that sense. When the perimeter of a circle is supposed to consist of 360°, (or 21600 minutes), the semi-diameter becomes equal to 3438'; or the sine of 90° is equal to the semi-diameter. Hence, by "trijā" is generally meant a line whose length is 3438'.

centric calculation or 'sighra-karma'). Another circle should be drawn with a point for its centre, which should be away from the centre (of the orbit circle) at a distance equal to maximum 'sighra phala' and in the direction of the 'sighra' position. This circle is termed as 'sighra'-eccentric circle. The same becomes a 'kāvā-vitta' (orbit circle) in the heliocentric operation. Again, draw another circle, in the direction of the heliocentric position, having its centre at a distance of maximum equation of centre. This is termed 'manda'-eccentric circle. Saturn, Jupiter and Mars, while moving in the 'manda eccentric circle' are seen occupying certain places in the heliocentric orbit circle, and they are termed 'heliocentric'. (These are the heliocentric positions of Saturn, Jupiter, and Mars). They should similarly be treated as moving in the 'sighra'-eccentric circle and their corresponding positions in the 'sighra'-orbit circle would be called their 'true position'. (These should be taken to be their geocentric positions). The circle having the earth for its centre, becomes the 'Manda' orbit circle for Mercury and Venus. The centres of their 'manda' eccentric circles lie at a distance, equal to their maximum equation of centre, from the centre of the orbit. The point of this circle occupied by the Sun should be taken to be the centre of the geocentric eccentric circle. The size of this circle has been mentioned as being equal to that of his 'own-geocentric-circle'. Mercury and Venus always move in that circle.

The underlying theory of the equation of centre is explained in another way by assuming a circle known as the 'nicocca-vitta' (apsidal circle). BHASKARA CARVA observes in this connexion :—

कक्षास्य मध्यवृत्तिवृत्तौ यत् त्रिखंडं दृश्यते तत् ।।

नीचोच्चयो रवेण कक्षयो मध्यवृत्तिरेव ।। २४ ।।

कक्षयो रवेण रेखायुते त्रिखंडे प्रकल्प ।।

नीचं तथासितरेषु त्रिखंडं, नीचोच्चमध्य रेखेच्छेदौ ।। २५ ।।

नीचोच्चवृत्ते मणालिकतेरिमं यदि विनामं निबद्धमिह ।।

यौ मध्यवृत्तौ मणालि रेखेयुदात्तय मध्यवृत्तौ हि प्रमाते ।। २६ ।।

अतो मणालि मृदुशीघ्रकंदं देयं निचोच्चवृत्तरेवदेव ।।

इत्युक्तमिहकारः ।।

"Draw a circle with the mean planet in the orbit, as centre, and the sine of maximum equation of centre as the radius. It is called 'the apsidal' circle. Draw a line from the centre of the earth passing through the mean planet. It intersects the circumference of the epicycle in two points—the farthest point is called the 'ucca' (aphelion) and the nearest one the 'mica' (perihelion). Draw a horizontal line in between the aphelion and perihelion. Mark the signs and degrees on the circumference of the 'nicocca'-circle. The mean planet moves from the aphelion in the manda (heliocentric) epicycle in a regular direction, and in the Saighra (geocentric) epicycle in a reverse direction, at the same rate of motion as its anomaly (i.e. according to the motion of its mean anomaly or of the angle of commutation). Hence, the centres of the mean and true circles are to be marked in relation to the aphelion.



equation of centre is Zero. As the planet advances three signs or 90° from the aphelion, the value of the equation of centre gradually increases and then it continually decreases till it reaches the perihelion. It increases again for three signs more and finally decreases till it reaches the aphelion. In short, whatever change occurs in the mean motion of the planet is in relation to the aphelion. The Surya Siddhanta makes the following observation:—

अङ्गयुक्तः कालस्य पूर्वो भग्नभ्रमः । शीघ्रमदीयं पारमेयं शृङ्खलं गतिर्विशेषः ॥ १ ॥  
 तावत्सिद्धहन्ताः स्युर्नरयतिभिः । शिफ्यस्यैवपुनो यथासं कालस्य ॥ २ ॥

एतद्विधम् ।

"The three invisible forms of time, viz. *śighrocca*, *mandocca* and *pāta* which are supported by 'bhāganas' (revolutions) are the generators of the motions\* of planets. These forms of time drag towards themselves by tossing and fro\*\* the planets which are tied by the reins of wind held by them." No other *siddhanta* has given so much importance to the *aphelia* as the S. S. has done by regarding them as some animate objects. *Brahmagupta* simply remarks,

पतिपदयाम्येषाः शक्तिपदाः \*\*\* : शृङ्खलैस्तथा पताः ॥ २६ ॥

शक्तिपदम् ।

"The *aphelia* and nodes have been imagined as points simply to explain the phenomena of planetary motions."

Nowhere does the S. S. explicitly state that the planets move in the epicyclic orbits; hence, it appears that the *aphelia* have been supposed to be some objects having forms. But when the planets are assumed to be moving in epicyclic orbits, their mean positions naturally undergo a change which simply depends upon the distance of the planet from the aphelion.

It has been mentioned above that the epicycles are supposed to be drawn at a distance from the centre of the orbit circle equal to the sine of the maximum value of the equation of centre or the annual parallax. The value of the equation of centre or of the annual parallax concerning each planet is given in our treatises, and it is the convention to give it in terms of the circumference of a circle, having the sine of maximum correction (viz. equation of centre) as semi-diameter; in other words it is what the length of the circumference, expressed in degrees, would be, if a circle be drawn with the sine of maximum correction as semi-diameter; and it is generally termed 'Paridhi' or 'circumference'. The circumference of the circle drawn with respect to the equation of centre is called the "mandapariidhi" i.e. the dimension of the epicycle of the apsis, and that with respect to the annual parallax is called the 'śighrapariidhi' or the dimension of the epicycle of the apex. The reason for expressing the equations in terms of epicycles seems to be the above system of drawing the epicycles of apsides. Considered independently, the circumference of the apsidal circle no doubt represents 360°; but as the value of the equation is to be reckoned in terms of degrees of the orbit circle, the length of the perimeter of an epicycle is also expressed by the same system of degrees.

\*Here, the word 'motion' is to be taken to mean true motion.

\*\*By "to and fro" is meant the actual position in advance of or behind the mean position of a planet. (*Ranganaṭha* has interpreted this in a somewhat different way). The position of a planet in the north or south direction changes because of the nodes.

The next table gives the dimensions of the epicycles related to the apsides and the apex as given by different authors; similarly, their radii also have been calculated and given. The radii themselves represent the maximum values of their equations. While calculating the radius, the ratio of the circumference to its radius as mentioned by Aryabhata I and Bhāskara II, viz. 62832 : 10000, has been adopted.

The arc of anomaly containing 3 signs or 90° is termed 'pada' (quadrant). The first and third are termed 'oja' (odd) and the second and fourth 'Yugma' (even). The authors of some siddhantas hold the view that the length of the circumference related to the odd quadrants is different from that of the circumference of the even quadrants; and that it varies in the intermediate portions proportionately. In the following table, the *paridhis* of some planets according to the Pañcasiddhāntikā have not been given, because the figures as given in that work are not known for certainty. In the case of other siddhantas, wherever the *paridhis* related to the even quadrants are not mentioned, they are to be taken to be equal to those related to the odd quadrants.

### MANDAPARIDHI

Dimensions of the Epicycles of Apsis and their radii or max. value of the equation of centre.

Planet	Modern Śūrya Siddhānta				First Ārya Siddhānta			
	The S. S. from Pañca Siddhāntikā		At the end of odd quadrant		At the end of even quadrant		At the end of even quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
Sun	14	2 13 41	13 40	2 10 30	14	2 13 41	13 40	2 10 30
Moon	31	4 56 2	31 40	5 2 24	32	5 5 35	31 30	5 0 48
Mars	70	14 8 27	72	11 27 33	75	11 56 12	63 0	10 1 36
Mercury	28	4 27 23	28	4 27 23	30	4 46 29	31 30	5 0 48
Jupiter	32	5 5 35	32	5 5 35	33	5 15 8	31 30	5 0 48
Venus	11	1 45 2	11	1 45 2	12	1 54 35	8 0	2 5 53
Saturn	48	7 38 22	49	7 47 55	40	30	6 26 45	
Planet	Brahma Siddhānta				Second Ārya Siddhānta			
	At the end of odd quadrant		At the end of even quadrant		At the end of odd quadrant		At the end of even quadrant	
	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
Sun	13 40	2 10 30	13 40	2 10 30	13 40	2 10 30	13 40	2 10 30
Moon	31 36	5 1 45	31 36	5 1 45	31 34	5 1 26	31 34	5 1 26
Mars	70 0	11 8 27	70 0	11 8 27	65 30	10 25 29	65 30	10 25 29
Mercury	38 0	6 2 52	38 0	6 2 52	27 36	4 23 34	27 36	4 23 34
Jupiter	33 0	5 15 8	33 0	5 15 8	28 15	4 39 46	28 15	4 39 46
Venus	9 0	1 25 57	9 0	1 25 57	9 35	1 31 31	9 35	1 31 31
Saturn	30 0	4 46 29	30 0	4 46 29	52 42	8 23 15	52 42	8 23 15

# Dimensions of the EPICYCLES OF APEX and their radii or max. value of the annual parallax.

Planet	The S. S. from Pancha Siddhantika	Modern Surya Siddhanta	First Arya Siddhanta
	At the end of odd quadrant	At the end of even quadrant	At the end of odd quadrant

	Circum	Radius	Circum	Radius	Circum	Radius	Circum	Radius
Mars	234	37 14 32	232	36 55 26	235	37 24 5	238 30	37 57 30
Mercury	142	21 0 30	132	21 0 30	133	21 10 3	139 30	22 12 7
Jupiter	72	11 27 33	72	11 27 33	70	11 8 27	72 0	11 27 33
Venus	260	41 22 49	260	41 22 49	262	41 41 55	265 30	42 15 20
Saturn	40	6 21 58	40	6 21 58	39	6 12 25	40 30	6 26 45

Planet	First Arya Siddhanta	Brahma Siddhanta	Second Arya Siddhanta
	At the end of even quadrant	At the end of odd quadrant	At the end of even quadrant
Mars	Circum 229 30 Radius 36 31 33	Circum 243 40 Radius 38 46 50	Circum 230 59 Radius " " "
Mercury	Circum 130 30 Radius 20 46 11	Circum 132 Radius 21 0 30	Circum 134 30 Radius 21 24 23
Jupiter	Circum 67 30 Radius 10 44 35	Circum 68 Radius 10 49 21	Circum 69 30 Radius 11 3 40
Venus	Circum 256 30 Radius 40 49 23	Circum 263 Radius 41 51 28	Circum 258 41 3 43 Radius 261 30
Saturn	Circum 36 0 Radius 5 43 46	Circum 35 Radius 5 34 13	Circum 40 40 Radius 6 28 20

The maximum values of the equation of centre according to Ptolemy and those according to modern European astronomers have been given below in a table.\* One can, of course, compare them with the above values given in our old treatises. But in order to facilitate such comparison, the maximum values of the equation of centre at the end of the odd quadrants, as given by Aryabhata I, out of our siddhantas, have again been given below :—

## MAXIMUM VALUES OF EQUATION OF CENTRE

First Arya Siddhanta	Ptolemy	Modern
----------------------------	---------	--------

Sun	2 8 55	2 23	1 25 27
Moon	5 0 48	5 1	6 17 13
Mars	10 1 36	11 32	10 41 35
Mercury	5 0 48	2 52	25 40 43
Jupiter	5 0 48	5 16	5 31 14
Venus	2 51 53	2 23	0 47 11
Saturn	6 26 45	6 32	6 26 12

\* These have been adopted from the translation of the Surya Siddhanta by Burgess (p. 76).

The modern values of Mercury and Venus cannot properly be compared with those given in our works, because the modern values are true only with respect to an observer on the Sun's disc while our works have given them with regard to the observer on the earth. It would not be wrong, however, if the values of other planets from both the systems are compared; and when they are so compared, it will be seen that the values given in our works agree with the modern ones to a great extent. The orbits of the moon and the planets are elliptical according to the modern astronomical theory. The value of their equation of centre varies with the changing values of the eccentricity of their orbits; and these values of the equation of centre as given in our works agree with the values given in modern works. The form of planetary motions as given in our works has been shown above which will show that although the writers of our works have not assumed an elliptical orbit for the movement of planets, still they have assumed that their distances from the centre of the orbit never remain the same, and that the equations vary with their position with respect to the points of apices known as aphelion and perihelion, in the orbit; from this it would appear that ancient authors indirectly knew the main cause of the difference between the true and mean places of planets, that is the phenomenon of the movement of these planets (or of the Moon) in elliptical orbits. The annual parallax of a planet depends upon the variable distance of the planet's heliocentric position in its orbit from the earth. The figures showing the annual parallax as given in our works have been given in the above table (page 243) and it has been pointed out before (page 197) that the radii vectors of planets calculated from them agree with the corresponding modern values. This fact coupled with the trend of the above discussion will show that our astronomers indirectly knew the second factor which was responsible for the difference between the true and mean position of a planet,—that the position of a planet with respect to the Sun, which is known as its heliocentric position, differs from the positions seen by an observer on the earth, because the earth also revolves round the Sun.

That none of the values given by PTOLEMY agree with the corresponding values given in our siddhāntas is one out of the many proofs\* to show that Ptolemy had no concern with any of the siddhāntas.

Now some more noteworthy facts about the epicycles of apses and apices may be mentioned. According to some siddhāntas, the dimensions of epicycles are different in the odd and even quadrants. ARYABHATA I has shown much variation in these dimensions; the Sūrya Siddhānta does not mention so much variation. BRAHMAGUPTA has assumed different dimensions for the epicycles in the odd and even quadrants only in the case of Venus. The modern Rōmaśa, Soma, Sakalya Brahmasiddhānta and Vasīṣṭha siddhānta are almost similar to the modern Sūryasiddhānta; still the measures of epicycles, as given in the Rōmaśa and Soma have been assumed to be the same throughout, and they agree with those of the even quadrants mentioned by the S. S. The dimension of the apsidal epicycle of mercury, given by Soma siddhānta as 34, however, does not agree (with S. S.). The Vasīṣṭha

\*The Rōmaśa siddhānta of the Pañcasiddhāntikā gives 4°57' as the maximum equation of centre for the Moon (See 8.6. Pañc S.). This does not agree with that given by Ptolemy. This is one of the proofs to show that the Rōmaśa Siddhānta of the Pañca Siddhāntikā was not written by Ptolemy.

siddhanta does not mention\* the apsidal epicyles at all. The dimensions of the epicyles of the apices have been given, but they do not agree with those of the Suryasiddhanta, and hence they are given below :—

Mars 234 ; Mercury 133 ; Jupiter 71 ; Venus 261 ; Saturn 39.

These are the same for both the quadrants, and though they do not agree with the Surya Siddhanta, they are easily seen to be approximately mean measures of the two kinds of quadrants. The copy of the Sakalya Brahmasiddhanta in the author's possession does not mention any epicyles at all ; but there undoubtedly appears\*\* to be in this copy, a break at the place where they are expected to have been mentioned. They must have been given in the original work. *Lalla* being the follower of Aryabhata I, the measures of epicyles given by both of them are identical. Similarly BHASKARACARYA was the follower of Brahmagupta and both have therefore, given the same measures. But Bhaskaracarya has mentioned 50° as the measure of the apsidal epicycle of Saturn and 40° as that of its epicyles of apex. The Sundarśiddhanta of JNANARAYA has given measures of epicyles similar to those of the modern Surya Siddhanta. According to Muniswara, the author of Siddhanta Śātra-bhāṣya, it is illogical to assume different measures for the epicyles in the odd and even quadrants. He has given the mean values of the measures of the epicyles in the odd and even quadrants given in the modern Surya Siddhanta. Different Karana works show some variations in the measures of epicyles ; but it appears to be due to the fact that sufficient attention was not paid to their accuracy. There is nothing specially worth mentioning about them.

The modern values of the equations of centre are given above ; but they are not always the same. They vary with the lapse of time. The following table\*\*\* gives an idea of the long-period variation affecting the value of the Sun's equation of centre.

Years before Saka era	Maximum value of eqn. of centre	Years after Saka era	Maximum value of eqn. of centre
10000	2	31	0
9000	2	28	1
8000	2	25	1
7000	2	22	1
6000	2	19	1
5000	2	16	1
4000	2	13	1
3000	2	10	1
2000	2	7	1
1000	2	4	1
0	2	1	1

\* It is found neither in the edition printed at Varanasi nor in the version in the Decan College collection.

\*\* The second chapter begins abruptly after an incomplete line of the verse : "Maurva Catuṣke", which is given after 111 verses of the first chapter. The second chapter opens with an unexpected question. It seems that the epicyles may have been mentioned in between. It is surprising that the break was found precisely at the same place in the copies seen at Gwalior, Asta, and later on in the Anandaśrama copy (No. 4341).

\*\*\* This table has been taken from the Planetary Tables of Ketopant.

The table shows that the correction due to the equation of centre, in the case of the Sun, is gradually diminishing. This correction, according to our works, ranges from  $2^{\circ} 13' 41''$  to  $2^{\circ} 8' 55''$ . It may be noticed that the more ancient treatises have given a greater value and the modern works a smaller one, as can be seen from the above table (page 242). It is easily seen that the value was determined after actual observations were taken at different times. Our astronomers have determined the correction figures for the Sun and Moon from the observations of their eclipses, that is from their positions at the moments of lunations. The modern European method of finding the true place of the Moon from that of its mean place, requires the application of five main corrections. It has been shown further that our people had determined a value as the maximum equation of centre for the moon, which is equal to the sum of the four (out of five) corrections applicable at the moment of lunation. The maximum value of the fifth correction of the equation of centre is 11 minutes. (Planetary Tables, by Keropant, p. 105). As its argument is Sun's anomaly, it was taken to be applicable to the Sun with minus or plus sign, where it was actually to be applied to the Moon with plus or minus sign. This has not affected the result of the calculation of the eclipse. If  $11'$  be subtracted from  $2^{\circ} 14'$ , which is the value of the sun's maximum equation of centre as given in our ancient works, our works can, in fact, be said to have given  $2^{\circ} 3'$  as the correction for the Sun, and that was actually the value in the year 500 B.S. Hence, our people appear to have found out the correction for the Sun at that early period or at least two or three centuries before Saka era. The equation of centre for the Sun, according to Ptolemy, is  $2^{\circ} 23'$ , which means that he had nothing to do with our works. Although Ptolemy has given  $2^{\circ} 23'$  as the Sun's correction, it was actually  $2^{\circ}$  in his time (about Saka 70). Obviously it was not found by Ptolemy himself, but probably adopted from some previous writer. The fact that no one except Hipparchus possessed, before him, the knowledge of calculating the true place of the Sun and the fact that the length of the year according to Ptolemy and Hipparchus was the same\* measure ( $365^{\circ} 14' - 48''$ ) lead one to infer that Ptolemy had adopted the value of the Sun's equation of centre from Hipparchus. This inference is further confirmed by the fact that the Romakak Siddhanta which was compiled on the basis of the work on Hipparchus has adopted  $2^{\circ} 23' 23''$  as the maximum equation of centre for the Sun. No one ever says that the Hindus borrowed astronomy from some work compiled after Ptolemy. No astronomer of equal capability flourished within 3 or 4 centuries after Ptolemy. None of our Siddhantas contain the same equation of centre for the Sun as was given in the original Romakak Siddhanta. From all these facts, any impartial thinker will have to admit that it is proved beyond all doubt that our astronomers did not borrow the figures for the equation of centre for the Sun from any European work, but that they themselves determined it before the Saka era.

The modern maximum values of the equation of centre that have been given above (page 242) show that the equation of centre for the moon is  $6^{\circ} 17'$ . But there are certain factors, other than the equation of centre, which cause a difference between the Moon's mean and true places; and these sometimes cause a variation of  $8'$  to  $8\frac{1}{2}'$  between the mean and true places of the Moon. For finding this, about 40 corrections are required to be applied. Of these, the correction known as the equation of centre, mentioned above, is a very large figure and the other four corrections are also appreciably large. Of

these, the one known as 'variation' (pākṣika or tāṭhik) has "moon minus true sun" as its argument. This argument will, of course, become 6 signs and zero at the moment of the full moon and the new moon respectively, and this correction too becomes zero\* at these moments. Similarly, for calculating the second of the four corrections, known as "evection" (cyuṭi), the argument is  $[2 \times (\text{corrected moon} - \text{true sun}) - \text{moon's anomaly}]$ .

The first term in this formula becomes zero at the moment of the full moon and new moon; and the argument is reduced to (zero minus moon's anomaly) at that moment. When the value of the argument is three or nine signs, the correction attains its maximum value viz.  $1^\circ 20.2'$ . Hence, if the moon's anomaly at the time of the full or new moon is 3 or 9 signs, the argument for calculating the correction due to evection becomes "zero minus three signs", i.e. 9 signs or 'zero minus nine signs' i.e. 3 signs and the corresponding values of the correction due to evection become respectively  $+1^\circ 20'$  and  $-1^\circ 20.2'$ , and at that time, if the moon's anomaly is 3 signs, the equ. of centre becomes  $-6^\circ 17'$  and if the moon's anomaly is 9 signs, the equ. of centre becomes  $+6^\circ 17.33''$ .

Hence at the moments of full or new moon, the maximum value of the correction, as given by the equation of centre and the evection together, would not exceed  $\pm 1^\circ 20' \pm 6^\circ 17' = \pm 4^\circ 57'$ .

One correction of  $11'$  out of the four has been applied to the Sun as already explained. The fourth correction is about 7 minutes.\*\*\*\* Applying it to the above figure of  $4^\circ 57'$ , we get  $5^\circ 4'$ . The remaining 35 out of 40 corrections are very small. In short, the maximum value of the moon's equation of centre as given by our siddhāntas, which lies between  $4^\circ 56'$  and  $5^\circ 6'$ , has proved to be very accurate. The best means of testing the accuracy of the values of the equations of centre in the case of the sun and moon are the eclipses; and it has already been observed before (pages 60, 130 etc.), that our astronomers have determined the corrections for the Sun and Moon with the aid of the eclipses.

Sudhākara states that *Munjal* has mentioned a correction similar to that of evection and another like variation, and that *Nityānanda* has mentioned those for variation and for the nodes.

No Western astronomer before *Ptolemy* knew how to find the true places of the five planets; even *Hipparchus* did not know it††. And the maximum values of the equation as given by *Ptolemy* do not agree with those given in our works. This shows that our astronomers have themselves found out the method of calculating the true places of the five planets. The calculation of the true places of the Sun, Moon and the five planets is the most important part of mathematical astronomy; in fact it is the quintessence of astronomy, and this we have decidedly not borrowed from Westerners.

\* Keropant's Planetary Tables, p. 110.

\*\* Keropant's Planetary Tables, p. 106.

\*\*\* Keropant's Planetary Tables, p. 109.

\*\*\*\* Keropant's Planetary Tables, pp. 105 & 111.

† The above explanation about the equation of centre relating to the Sun and Moon was suggested by Venkates Bāpuji Keikar.

†† Grant's *History of Physical Astronomy*, Chap. XVIII.

The equation of centre is found by the formula  
*epicycle X sine of anomaly of planet.*  
 semi-diameter

The 'Kendra' (anomaly) is the difference between the place of the planet and that of the aphelion. The Sun and Moon require only one correction, that of the equation of centre. Others require two corrections, the equation of centre and the annual parallax. The calculation requires the use of the planet's distance from the earth; and in order to find the equation of centre accurately, one has to use the method of successive approximation.

### *Sines and Radius*

The Siddhanta works give sines of divisions of circle, each of which is equal to  $3\frac{1}{2}^\circ$ . The Karapa works use divisions consisting of  $10^\circ$  to  $15^\circ$ , each since they are not very particular about accuracy. Most of the Siddhantas have assumed 3438 as the value of 'trijya' (radius) while calculating values of sines. Brahmagupta has assumed it to be 3270. Kamalākara, the author of Siddhantatattva-viveka has mentioned sines of each degree of the quadrant assuming 60 as the value of the 'trijya'. The Karapa works generally take 120 as the value of the 'trijya'. According to Sudhākara, Munja has adopted 8' 8" as the 'trijya' and Gangādhara, author of Candramāna (page 195) has adopted 191 as the measure. The work Yantraj has adopted 3600 as the 'trijya' and given the sine of each degree of the quadrant. Keroṣant Nāṇa remarks that the value of 'trijya', 3438, which this Hindu astronomer adopted is an awkward figure entailing unnecessary multiplication and division. This is to a certain extent, true. But our astronomers have at places made use of artifices to avoid lengthy multiplications and divisions; and the reason for adopting that figure for the radius is a rational one, inasmuch as the circumference of the circle is equal to 21600 minutes and the radius computed from it comes to 3438. The most accurate ratio of the diameter to the circumference is 1 : 3.1415927. On the basis of this ratio, if the circumference be 21600, the semidiameter comes to 3437 $\frac{1}{2}$ . Our astronomers have adopted 3438 as the value after leaving out the fraction. This will show that the value of 'trijya' adopted by our astronomers is very accurate. Our ancient authors have assumed different figures as the ratio of the diameter to the circumference. They are given below :—

Sūrya Siddhanta, Brahmagupta, Aryabhata II	1 : $\sqrt{10}$ or 1 : 3.1623
Aryabhata I	20000 : 62832 or 1 : 3.1416
Aryabhata II & Bhaskaračarya**	7 : 22 or 1 : 3.1428
Bhaskaračarya	1250 : 3927 or 1 : 3.1416
3438 as the radius gives	1 : 3.14136
Precise Modern European value	1 : 3.1415927

Evidently our people had a very accurate knowledge of the ratio of the diameter to the circumference. If they have, at places, adopted an approximate value, it is only with a view to simplifying calculations in practical work.

\* See Planetary Tables, page 314.

† The European mathematicians assume the value of a 'trijya' as equal to the 10th or some other power of 10. They have ready made tables for the purpose, which give sines and other ratios of each minute of arc; and as the 'trijya' is a very large number greater accuracy is ensured.

\*\* Aryabhata II and Bhaskaračarya each has mentioned this ratio in two ways.

Brahmagupta has given in the following verse the reasons for adopting 3270 as the value of the semi-diameter:—

यथावृत्तस्य यथा वर्गयुतौ न वर्गयुतः  
यथात्रिंशत् न वर्गयुतौ न वर्गयुतः ॥ १६ ॥

शेषवत्

Accurate calculation shows that the radius, corresponding to 21600 as the circumference, is not the whole number 3438, and it is true that because of this the "first sines" are not very accurate. But the author does not think that the value of the semi-diameter viz. 3270 which Brahmagupta has adopted on the basis of the ratio  $1 : \sqrt{10}$  of the diameter to the circumference or by some other method can be justified.

The question of calculating sines and their origin has been dealt with as great length by Bhaskaracarya. Even the author of Siddhantatattvaviveka has given much thought to it. It is not necessary to deal with it here in detail. Playfair (1782 A.D.), an European scholar, observes about the origin of sines in our treatises, "The method devised by Hindu astronomers to find the sines implies the following proposition:—'The ratio of the sum of the sines of the first and the last of three arcs in arithmetical progression to twice the sine of the middle one is equal to the ratio of the cosine of the difference of the arcs to the radius'—This proposition was apparently not known to European mathematicians till the beginning of the 17th century". It is really creditable to our people. Similarly the Greeks only knew what a chord is, but they did not know to make use of the first sines (jyārdha). Even the Arabs didn't know of it till the 9th century A.D. It has been pointed out in the account of Aryabhata I that it was known to our astronomers from Saka 421. Our people, however, did not have an idea of the tangent and the secant. Their purpose was, however, served by sines alone.

#### OTHER MATTERS

The question of finding when planets become direct or retrograde and when they rise and set, these and other like matters of secondary importance are dealt with in the chapter on true motions. It is not necessary to deal with them at length here.

#### DECLINATION

Our works assume  $24^\circ$  as the maximum declination of the Sun. The obliquity of the ecliptic had reached that value 2400 years before the era. It is  $23^\circ 27' 10''$  in the beginning of saka 1818. This means that the maximum declination at the present time, as calculated from our works, is wrong by  $32' 50''$ . The obliquity about Saka 400 was about  $23^\circ 39'$ . Ptolemy's work (SYNTAXIS, Part I) mentions it as a value lying between  $23^\circ 50'$  and  $23^\circ 52' 30''$ , and it seems to be Prof. Whitney's opinion\* that he borrowed this value from the works of Hipparchus. As this value of obliquity does not agree with the value given in our works, it is obvious that our people did not borrow their figure from the works of Hipparchus and Ptolemy. They must, of course, have found it independently and some time before the Saka era. The work entitled, Yantiraj, assumes  $23^\circ 35'$  to be the obliquity. (In fact, this was correct about Saka 900). But no later writers accepted it nor did they attempt to find it for themselves.

\* Asiatic Researches, Vol. IV.  
\*\* Translation of the *Suryasiddhanta* by Burgess, p. 57.

## CHAPTER II

## PANCANGA

## (Almanac)

The calculation of the five elements or parts (*angas*) of the Almanac (*Pancāṅga*) is usually given in the *Spaśādhikāra* (the chapter on true Places); and hence, the question of the almanac is being taken up in this very chapter. Such matters as the Saka era, the beginning of the year, the *samvatsara* (year), the "pūrṇimānta" and "amānta" systems etc. are but integral parts of the almanac; after considering these, therefore, the consideration of the five elements of the almanac, the different kinds of almanac etc., will be taken up.

Astronomical calculations require some moment of time to start with in order to predict future planetary positions. In accordance with this convention, the siddhanta works assume the commencing moment of Mahāyuga or that of some other Yuga and especially that of the Kaliyuga as the starting moment for calculation; and the Karana works assume some particular year of the Saka era as the commencing year. A Karana work, however, can be found to have adopted Vikram Samvat along with the Saka era. Thus the Karana work *Rāmavīṇod* has adopted Akbar year along with the Saka year, and the *Phaṭṭeśāha Prākāśa* has adopted the Phaṭṭeśāha year coupled with the Saka year. The *Vārṣikāntara* (page 167), which is really a Karana work has adopted the commencement of the Kaliyuga for the epoch for calculation, and the author has accordingly classed the work as 'tantra'. Even then it has brought in some association with the Saka era.

## A study of different eras

Our almanacs, in their opening pages which are usually devoted to the study of the "samvatsaraphala" (forecast of the year), refer to six founders of these, Yudhiṣṭhira and the other to lived in the past and the remaining three are yet to be born. The word Saka, in fact, denotes a certain tribe of people. Bhātopala and others have stated that the era was introduced under the name of Saka, since the time when Vikrama defeated the Saka kings. But this does not appear to be reasonable. The Saka kings themselves may have started the reckoning of the era in their own name. The word Saka originally denoted a particular tribe, but in compound words like Yudhiṣṭhira Saka, Vikrama Saka etc., it signifies time, generally known as 'Era' in English and as 'Sā' in Arabic. The word 'Kala' (time) is found to have been used in the sense of era in ancient copper plates. For instance, Sakāntpa Kala, Vikrama Kala, Gupta Kala (meaning—the era started in the name of Gupta Kings) are some examples of the usage of the word. Hence, the word Kala has been used in the sense of era in the discussion which follows.

## Expired year and current year

A number of eras like Vikrama era and Saka era had been and still continue

Before doing so, however, let some idea be given about two types of the year : the expired and the current. In the account of *Brahmagupta* (page 90) the date of compilation of the *Uttara Purana* has been stated to be Saka 820. But the positions of planets, purporting to be true for the year 820, are found to agree with those for what would be Saka 819, according to the present mode of reckoning. Hence, one begins to doubt whether the real date of compilation of the *Purana* was Saka 819 or 820. The Saka year which is mentioned as "Saka 1818" by the almanac-makers of this province and of most of the Provinces in our country is found to have been counted as Saka 1819 in the Tamil and Telugu almanacs and in some of the Kannad ones printed in Mysore. The reason for this difference appears to be this : The positions of planets given in Siddhanta works are true for the initial moment of the first year of the Kaliyuga. Supposing the positions of planets in the beginning of the 11th year of the Kaliyuga are required, they must be found by adding to the original positions the motion of planets for 10 years, since 10 years would have been elapsed from the beginning of the Kaliyuga to the desired moment. In such calculations the number 10 has to be taken instead of 11. The two dates of compilation of the above *Purana*, viz. 819 and 820 may possibly be accounted for in some such way. In other words 820 is the current year and 819 the expired year in this case. Similar examples are found in copper plate and other inscriptions. It has been pointed out above that the Saka year which is numbered 1818 in these parts is counted as 1819 in some almanacs of the Madras Presidency : But there is doubt if the people of that region are really aware of the difference between the expired and current years and if it is taken into account at all for practical purposes. Now-a-days the Tamil almanacs compiled by *Anna Ayyangar* of *Tanjore* District, are in general use in Tamil country of the *Madras* Presidency. The author has procured a number of such almanacs for the last several years. Among these, the almanac for the last Sarvajit samvatsara mentions the corresponding Saka year to be 1809, while the almanac for the very next year, known as Sarvadhari, compiled by the same author gives 1811 as the Saka year. These year were counted as 1809 and 1810 in other provinces. It seems that the almanac-makers themselves do not clearly understand the distinction between the expired year and current year ; how can we then expect others to understand it ? On enquiries made of the well-known *Natesh Sasiri* of *Madras* and the eminent scholars *Sundareswar Shrotri* and *Nankateshwar Dikshit*, from *Tiruvadi* in *Tanjore* District, the author has learnt that the year described as "current" above is not at all in vogue in those parts at present. Hence, there is reason to believe that the distinction between the expired and current years must be merely imaginary and that it arose when two different numbers might have been applied by someone to the same year by mistake. If any such distinction exists at all it can possibly be true only with respect to the Kali era and Saka era which are in use in works on astronomy ; and of these two, the distinction can be applied with greater clarity to Kali era. The Vikrama and other eras are not in use in astronomical works and no such distinction can be found in their case. However, examples are found in which two different numbers are applied to the same year of the Vikrama era ; but it must be the result of an error. In short, on full consideration, the author is led to believe that, as a matter of fact, there is no such distinction as expired and current year. All years are only current years. For example, the present year (when the author is writing this chapter) named *Durmukh* (Saka 1818) is actually 'current'. Later on, in the study of different eras, figures denoting corresponding years have been given

—and compared, and in so doing the system used for reckoning the year number is the same as the one prevalent in most parts of India. In some places the terms 'current' and 'expired' have been used; but they have been used for differentiation in the case of only those years, to which two different numbers are likely to be applied. Let us now consider the different eras.

### The KALI Era

The Kali era is used for calculating time in astronomical works and in almanacs. Its years are both *\*Caitradī* (luni-solar, beginning from Caitra) and *\*Mṛgāśīr* (Solar, beginning from Aries Ingress). The almanacs mention sometimes the current year of this era, sometimes the expired year and some-times both. It is not met with very often in epigraphical records. This era is not at all used for civil purposes at present. Some almanacs in the Madras Presidency, however, state the year only according to Kali era. The year (expired) according to Kali era is obtained by adding 3179 to the Saka year.

### The SAPTARŚI Era

This era is at present in use in *Kashmir* and the neighbourhood. It seems that it was in use in *Kashmir*, *Mulian* and some other parts at the time of *Albiruni* (Saka 952). The *Rāja-Taraṅgīnī* has described all historical events only in terms of the years of this era. The era is sometimes known as the "Laukika Kāla" (civil time) or the *Sāstra Kāla*, (scientific time). This system of measuring time originated in the supposition that the *Saptarśi* stars (the Great Bear) have motion, that they take 100 years to pass through one nakṣatra and that they revolve through the zodiac once in 2700 years; thus a cycle of 2700 years has been adopted for reckoning time. But in practice the century figure is usually left out. When 100 years are completed, the counting begins afresh as the first year, second, and so on. According to the astronomers in *Kashmir*, the *Saptarśi* era began from the first lunar day of the bright half of Caitra, in the current Kali year 27. In order therefore, to find the corresponding year of the Saka era, one has simply to add 46 to the *Saptarśi* year, neglecting the centuries; and similarly if 24-25 added one gets the year according to Christian era. The "Saptarśi" years are *Caitradī*. Dr. *\*Kielhorn* finds that the years in this system are 'current' and the months 'pūrṇimānta' (full moon ending\*\*).

### The VIKRAMA Era

This era is at present in use in *Gujerat* and the whole of northern India except *Bengal*. The people of these parts have migrated to other provinces but they have carried the use of the era with them. The year of this era is *Caitradī* in Northern India. (In other words, the Samvat begins from Caitra). The months are *pūrṇimānta*. But in *Gujerat* the year is *Kārtikādī* and the months are *amānta*. In some parts of *Kaithiawād* and *Gujerat* the Samvat year is *Aśvadhādī* and the months are *amānta*. Prof. *\*Kielhorn* has examined

*\*Caitradī* means "beginning from Caitra"; *Kārtikādī*, "beginning from Kārtika"; *Mṛgāśīr*, "beginning from Sun's entry into sidereal Aries". (R.V.V.)  
*\*\** Indian Antiquary, XX, page 149 ff XX.  
*\*\*\** The amānta and pūrṇimānta systems are discussed later on.  
*\*\*\*\** Indian Antiquary, XX, p. 398 ff.

